



مدیریت پروژه‌های صنعت ساخت (ساختمانی، زیرساختی و صنعتی)

فصل چهارم: مدیریت برنامه‌ریزی و زمان‌بندی
برنامه‌ریزی و زمان‌بندی پروژه
کنترل زمان پروژه، به‌روزرسانی و اصلاح برنامه

ارائه دهنده:

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What we will learn?

- ☐ Project planning
- ☐ Project scheduling concepts
- ☐ Manage time
- ☐ Project scheduling applications
- ☐ Project coordination
- ☐ CM roadmap related to this section

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PROJECT PLANNING



Introduction

- ❑ Project planning is **central** to project management.
- ❑ Planning takes place **at all stages**.
- ❑ The plan is typically very **simple in concept** (though it may be quite complex in execution), consisting of a few steps:
 - ❖ Identify the **need** as clearly as possible.
 - ❖ Determine a **budget** and **completion date**.
 - ❖ Bring together a **team** that can design and build the facility.
 - ❖ Monitor the **process** throughout the project's schedule.

Introduction

❑ In order for the **plan to be “workable,”** it requires careful **consideration of all of the activities** above and **buy- in from** all of the **construction team members**, including:

- ❖ General contractor’s officer-in-charge (OIC),
- ❖ Project manager (PM),
- ❖ Superintendent,
- ❖ Field foreman,
- ❖ Project engineer,
- ❖ Home-office staff support specialists, such as the scheduler, estimator, and quality and safety officers, and
- ❖ Subcontractors.

CPM Procedure

- ❑ Construction **time control** is a difficult, time-consuming, and arduous management function.
- ❑ The **Critical Path Method (CPM)** is just such an expedient and constitutes the **basis** for the ensuing treatment of **project time control**.
- ❑ This method applies **equally well** to
 - ❖ All construction work,
 - ❖ Large and small,
 - ❖ Intricate and straightforward

CPM Procedure

❑ CPM is a **three-phase procedure** consisting of planning, scheduling, and time monitoring or controlling.

1. **Planning** construction operations involves the determination of what must be done, how it is to be performed, and the sequential order in which it will be carried out.
2. **Scheduling** determines calendar dates for the start and completion of project components.
3. **Time monitoring** is the process of comparing actual job progress with the programmed schedule.

Planning phase

❑ Construction **planning** may be said to consist of **five steps**:

1. A **determination** of the general approach to the project.
2. **Breakdown** of the project into job steps or “activities” that must be performed.
3. **Ascertainment** of the sequential relationships among these activities.
4. **Graphic presentation** of this planning information in the form of a network.
5. **Endorsement** by the project team.

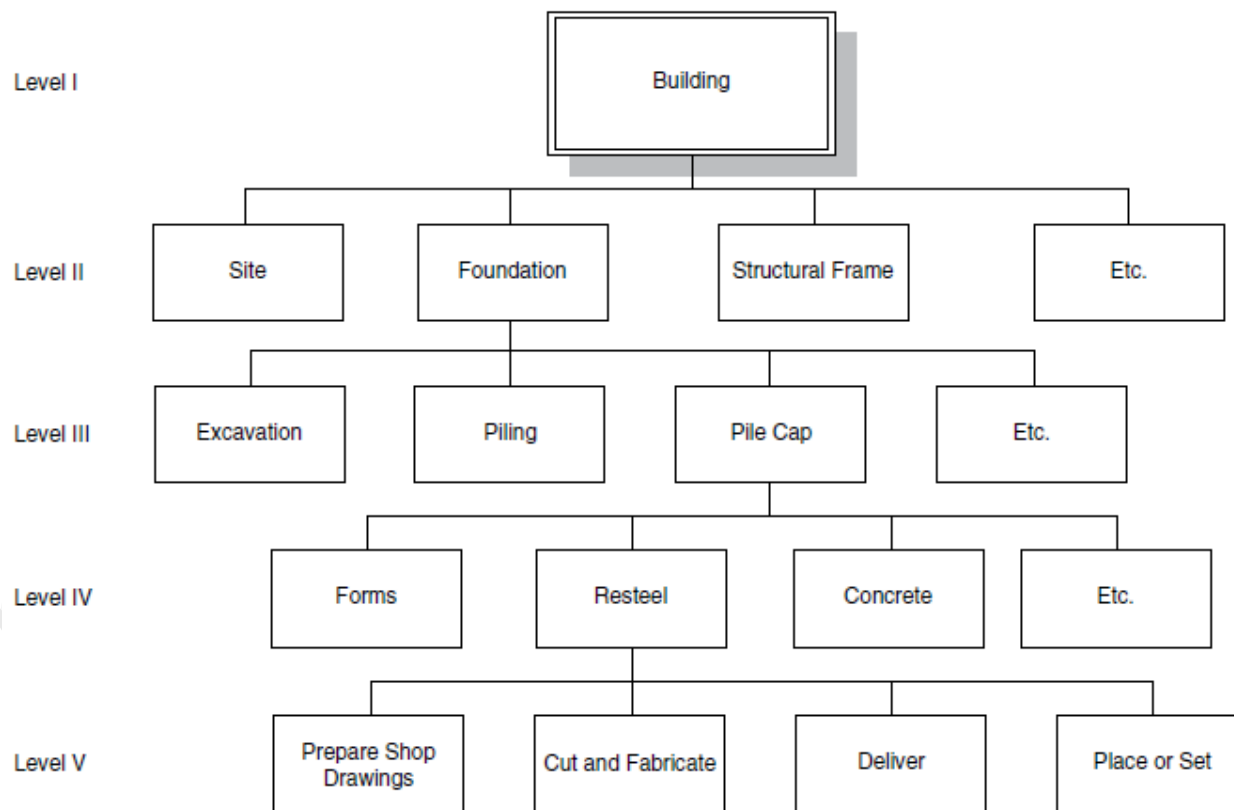
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Work breakdown structure (WBS)

- ❑ Project planning involves the **development** of an objective or facility and a scope of work defining the work product or deliverable.
- ❑ The **bid package** consisting of the plans and specifications establishes the **scope of work** to be performed.
 - ❖ To be properly managed, the **scope of work** must be broken into components that **define** work elements or building blocks,
which need to be **accomplished** to realize the end objective.
- ❑ The **assumption** is that the project is the summation of its sub-elements.

Work breakdown structure (WBS) – Example

- ❑ The Figure is an example of a WBS for a small building.





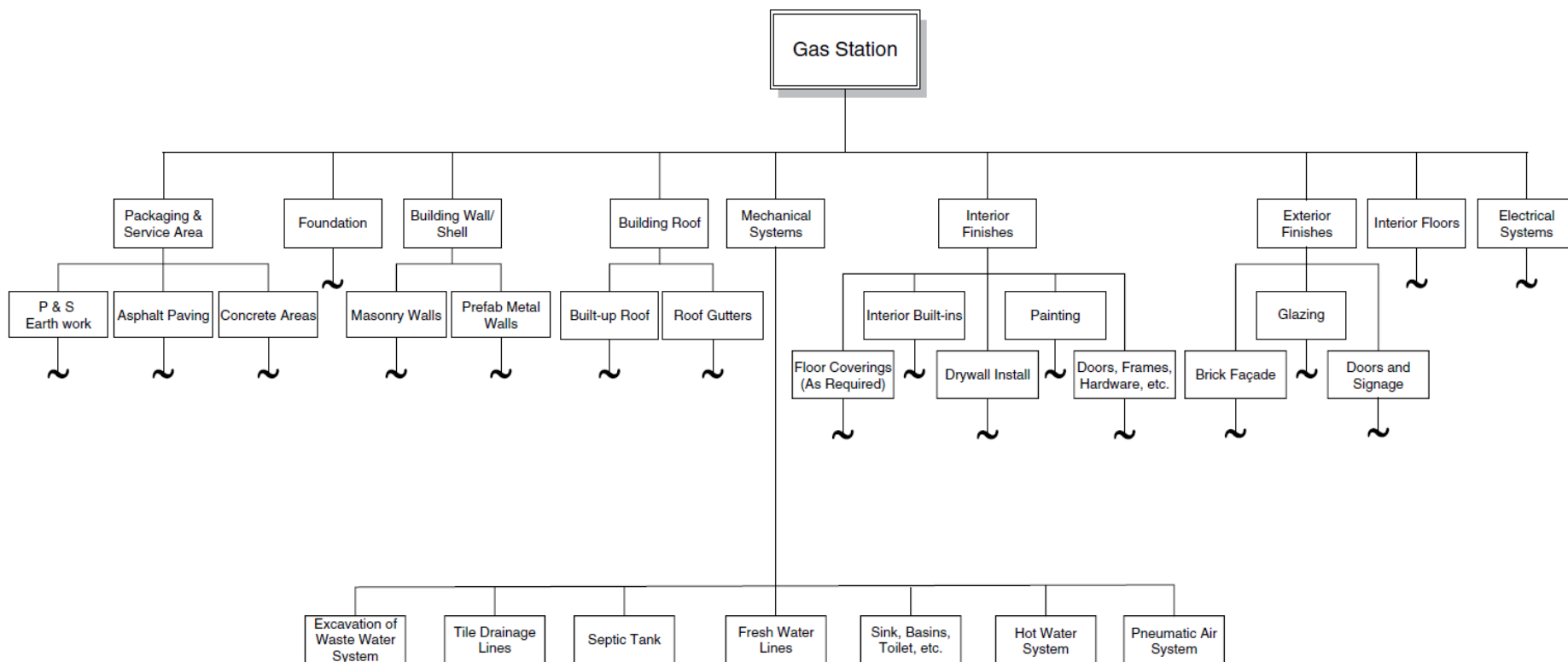
Work breakdown structure (WBS)

- Planning can be thought of as the **definition and sequencing** of the work packages within a given project. That is:

$$\text{Planning} = \text{Work Breakdown} + \text{Work Sequencing}$$

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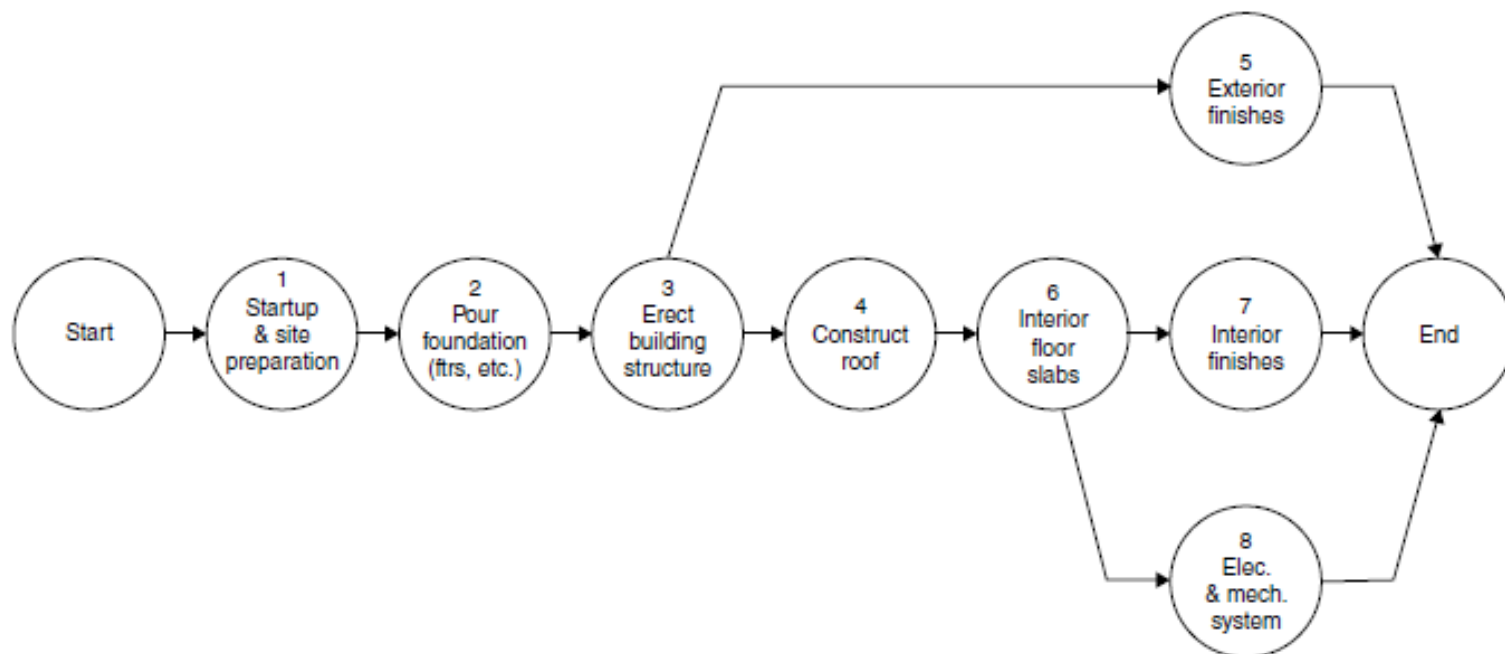
Work breakdown structure (WBS) – WBS for gas station



Determining sequence of work packages

- ❑ Having broken the work into **work packages**,
activities that **facilitate time management and control** can be
defined and logically placed in sequence.
- ❑ In **arranging the work package sequence** for time control, the criteria of
 - (a) location,
 - (b) material,
 - (c) method, and
 - (d) required resourcesmust be reconsidered from the **perspective of**
how these criteria impact the order or sequence of work activities.

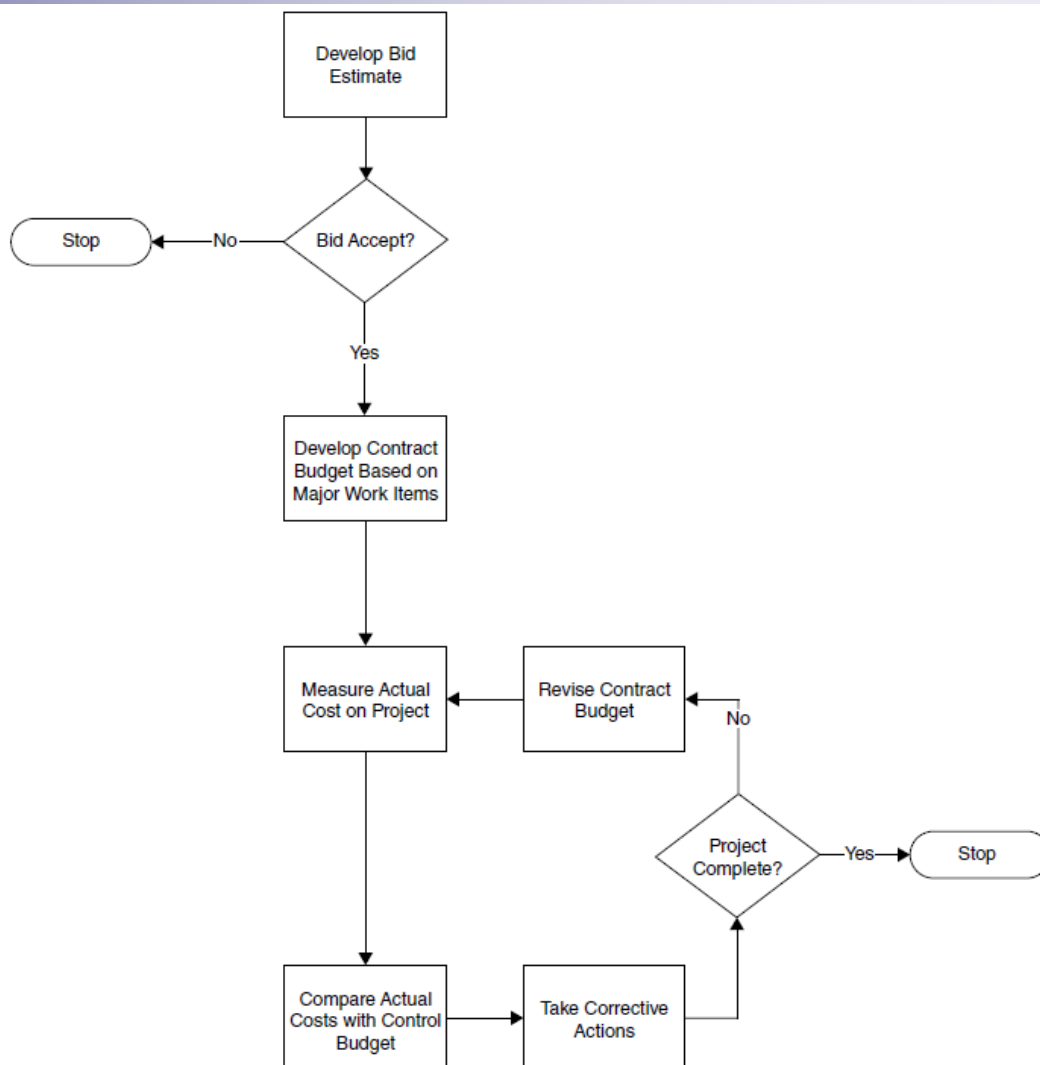
Determining sequence of work packages – Preliminary breakdown



Estimate development and cost control related to the WBS

- ☐ A **good WBS** facilitates cost control during the **life of the project**.
 - ❖ If a WBS is used, the major items are work packages.
- ☐ **Work packages** are defined so that they have their own unique budgets.
- ☐ When referring to **work packages** in the context of cost control, the terminology cost accounts or control accounts is often used.
- ☐ During the **bidding process**, the contractor prepares an estimate of cost that becomes the **basis for the bid price** submitted for the **proposed work**.
- ☐ If the **bid is accepted**, the detail estimate used for **bid submittal** is **converted to a budget** that serves as a cost baseline to control spending during the life of the project.

Estimate development and cost control related to the WBS



Role of code of accounts

❑ The development of **cost coding systems** is discussed in detail in the following course.

- ❑ A **typical cost code** might define
- (a) the project designator,
 - (b) area of work,
 - (c) work discipline (e.g., civil, mechanical, electrical, etc.), and
 - (d) the trade specialty required.



Role of code of accounts

Cost Code Structure (Example)

Level	Project	Area	Discipline	Trade
1	21300			
2		804		
3			724	
4				112

Cost Code = 21300.804.724.112

Role of code of accounts

Work Package Identification 06-123 Description: Concrete Placement Interior Floor Slabs						
	Materials					Actual Productivity
Resource Code	Description	Unit	Qty	Unit Cost	Extension	
101	Concrete, 2500psi	CY	30	40.00	1200.00	
						Notes
	Installed Equipment					
						Cost Summary
	Crew Labor	NR	Hours	Cost/Hr	Extension	
020	Foreman	1	8	30.00	240.00	
029	Laborer	4	8	15.00	480.00	
022	Finisher	1	8	20.00	160.00	Actual Cost Labor = Materials = Equipment =
063	Pump Operator	1	8	25.00	200.00	
Total					1080.00	
Equipment Not Charged As Indirects						
		NR	Hours	Cost/Hr	Extension	
505	Vibrator	1	8	10.00	80.00	
517	Finisher	1	8	15.00	120.00	
308	Concrete Pump	1	8	150.00	1200.00	
Total					1400.00	

Work package control account sheet (CII Cost/Schedule Task Force, 1988)

Job activities

- ☐ The segments into which a **project is subdivided** for planning purposes are called **activities**.
- ☐ An **activity** is a single continuous work step
that has a recognizable beginning and end and
requires time for **its accomplishment**.

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Job activities



Activities are made up of the verb (action), noun (what), and location (where).



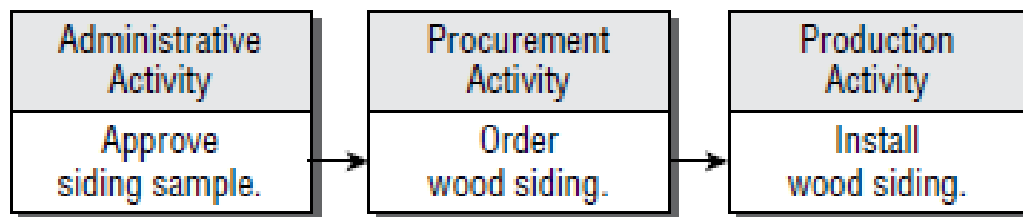
Job activities

❑ The extent to which a project is subdivided depends on a number of practical considerations, but these **eight are suggested as guidelines** for use when activities are being identified:

1. By area of responsibility, where work items done by the general contractor and each of its subcontractors are separated.
2. By category of work as distinguished by craft or crew requirements.
3. By category of work as distinguished by equipment requirements.
4. By category of work as distinguished by materials such as concrete, timber, or steel.
5. By distinct structural elements such as footings, walls, beams, columns, or slabs.
6. By location on the project when different times or different crews will be involved.
7. With regard to the owner's breakdown of the work for bidding or payment purposes.
8. With regard to the contractor's breakdown for estimating and cost accounting

purposes.

Job activities



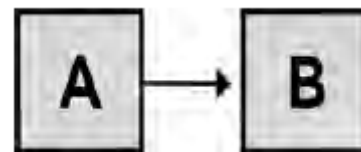
Job logic

- ❑ **Job logic** refers to the determined order in which the activities are to be **accomplished in the field**.
- ❑ The **start of some activities** obviously depends on the **completion of others**.
 - ❖ A **concrete wall** cannot be poured until the forms are up and the **reinforcing steel** has been tied.
 - ❖ **Much job logic** follows from well-established work sequences that are **usual and standard** in the trade.
 - ✓ Nevertheless, for a **project of any consequence**,
there is always **more than one general approach**, and
no unique order of procedure exists.

Who has the responsibility for this?

Job logic

- ❑ There are **various ways** that activities can be **logically linked together** to define sequence and interdependencies.
- ❑ As previously mentioned, **finish-to-start (FS)** is the most common form of relationship which means the previous task (predecessor) must be completed (finished) before the next task (successor) can start.

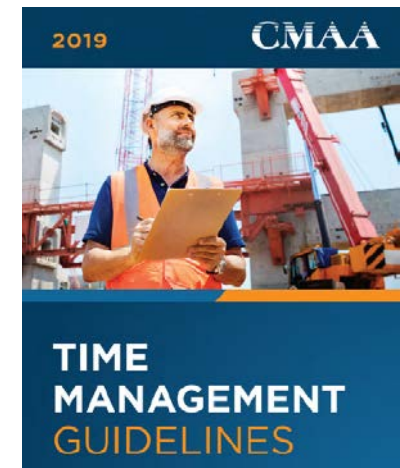


Job logic

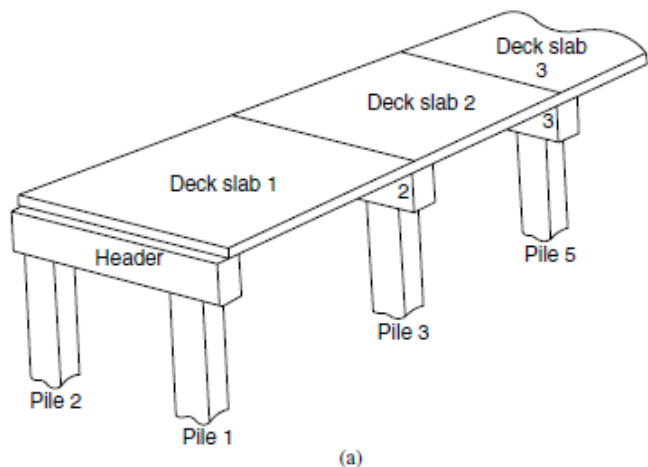
❑ Also, **logic relationships** may be in the form of

1. Hard logic, which means there is a **mandatory dependency**, or
2. Soft logic where dependency is **discretionary**.

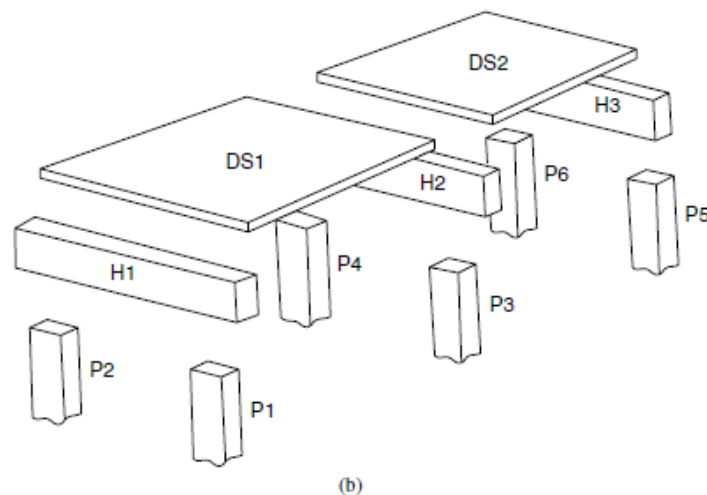
- ❖ *An example of hard logic would be activities that are related to each other based on **physical requirements** such as needing a wall before installing a roof.*
- ❖ *Soft logic refers to **managing resources (supplies and labor)**, handling cash flow, or creating a progression of activities.*



Job logic

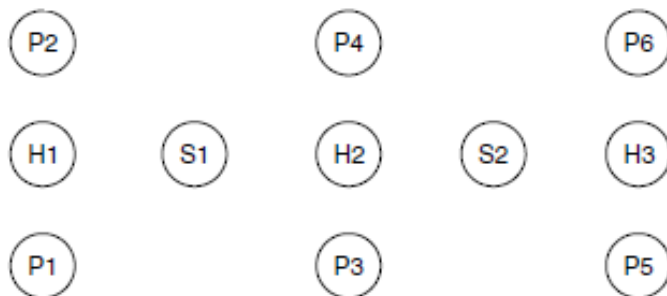


(a)

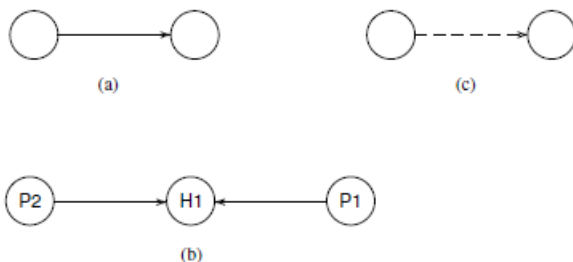


(b)

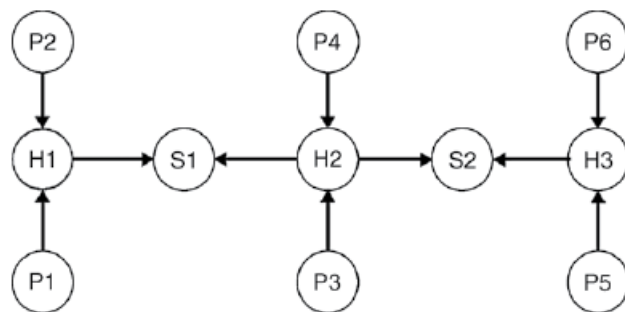
Conceptual model
of pier components



Job logic

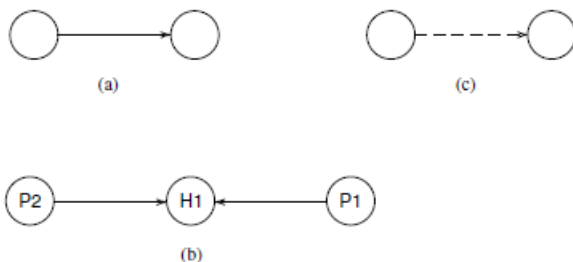


Logical modeling rationales: (a) adjacency of contact modeling; (b) physical structure order modeling; (c) physical construction order modeling

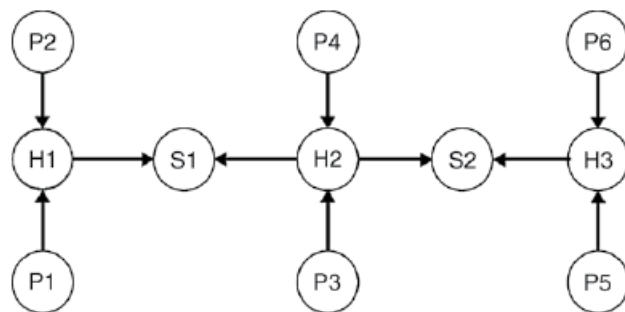


Conceptual model of pier component relationships

Job logic

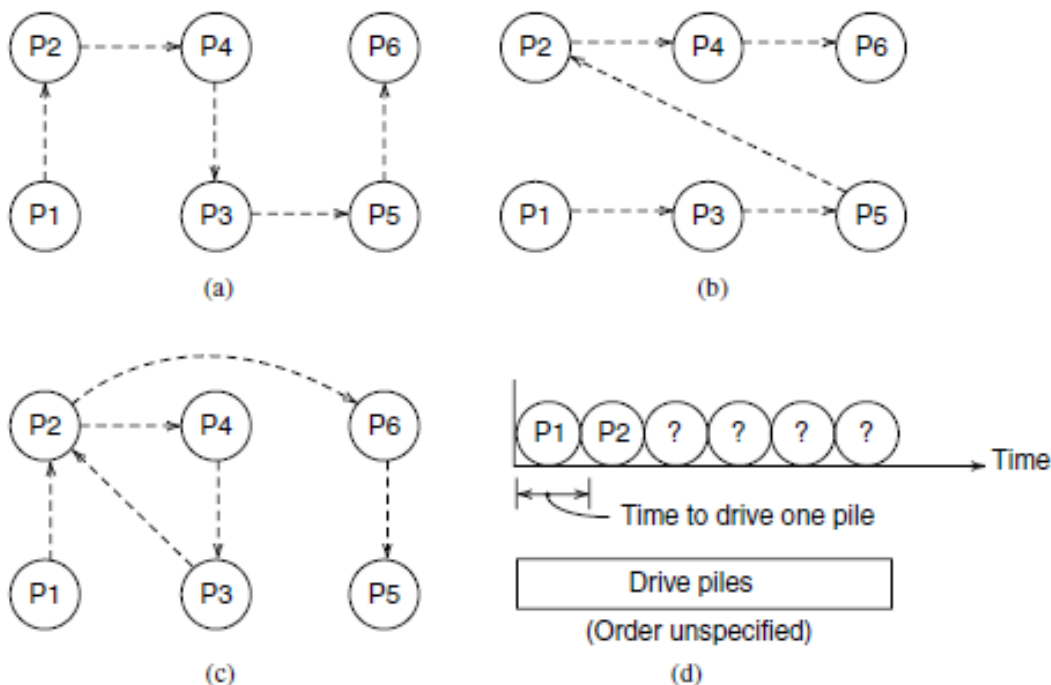


Logical modeling rationales: (a) adjacency of contact modeling; (b) physical structure order modeling; (c) physical construction order modeling



Conceptual model of pier component relationships

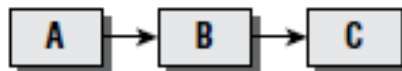
Job logic



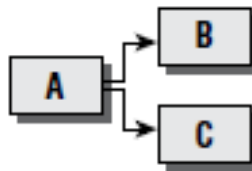
Construction sequence and activity modeling (Antill and Woodhead, 1982): (a) alternate row pile driving; (b) sequential row pile driving; (c) field mishap alteration to pile-driving sequence; (d) bar chart model of pile-driving operation

Job logic

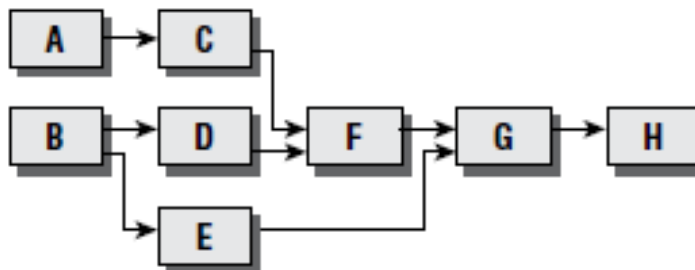
A must occur before B occurs, and C can't happen until B is complete.



A must occur before B and C can occur. B and C can occur simultaneously.



H cannot be done before G, and G is dependent upon the completion of E and F. F can't happen before C and D. D and E are preceded by B. C can't start until A is done.



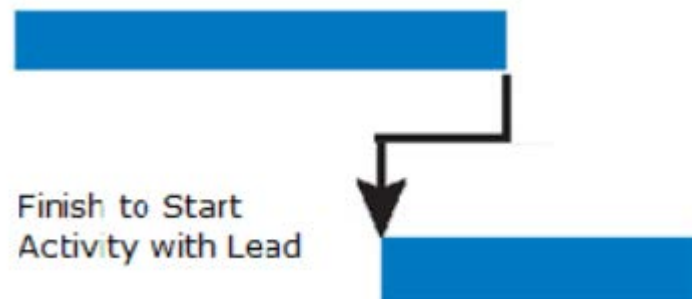
Lag relationships

❑ **Lead/Lag times** are used when **assumptions** around logic need to be introduced into the schedule.

❖ Lead time is the **overlap** between activities that have a dependency.

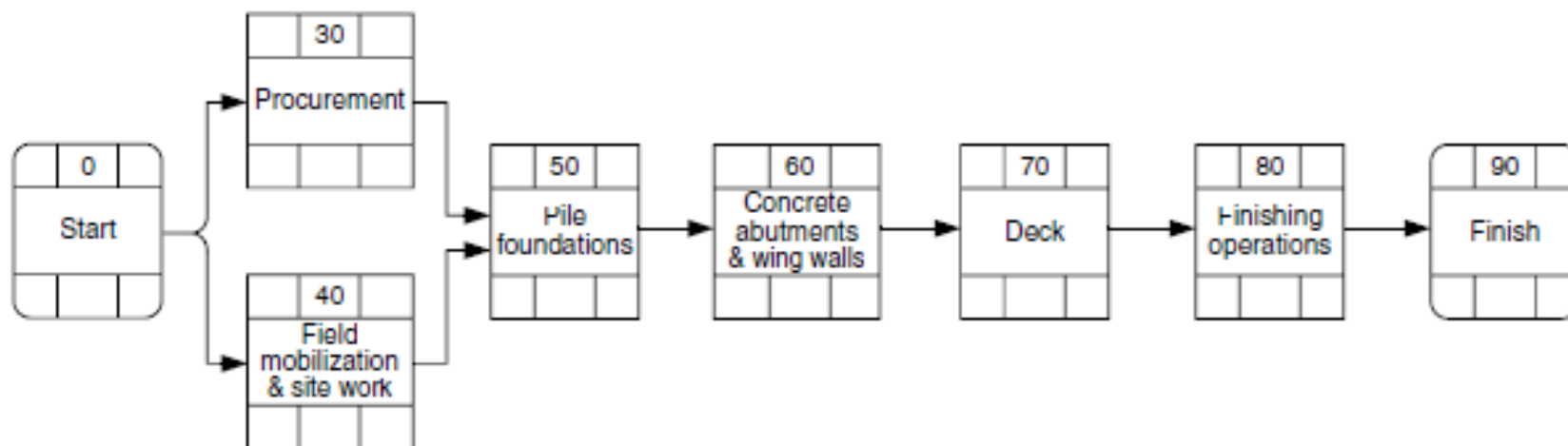
❖ Lag is a **delay between** tasks that have a dependency.

❖ *For example, if there is a three-day delay between the time one task finishes and the other one starts, that means there is a finish-to-start dependency with three days of lag time.*



Lag relationships – Highway bridge, general job plan

- ❑ The Figure has been drawn on the **customary basis** that a given **activity cannot start** until all of those activities immediately preceding it have been completed.



Restraints or constraints

- ❑ To be realistic, a job plan must reflect the **practical restraints** or **limitations** of one sort or another that **apply to most job activities**.
- ❖ The restrictions of job logic itself might be called **physical restraints**.
 - ✓ **Placing forms and reinforcing steel** might be thought of as restraints to pouring concrete.

However, there are other kinds of restraints that need to be recognized.

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Restraints or constraints

- ❑ **Almost all CPM schedules** have some **type of constraints** that must be considered.
- ❑ Three types of common constraints are date, duration, and float.
 1. Date refers to the **time allotted** for an activity.
 2. An example of duration is that **all work in one phase of the project** must be **completed in 240 days**.
 3. A float constraint may be used to **limit the amount of delay (or float)** an activity can have **without delaying** the project.

*As a rule, constraints should be **used sparingly** to ensure that there is **minimal impact** to schedule calculations.*



Restraints or constraints

- ❑ Many scheduling software packages provide the option to use date-related or float-related constraints.
- ❑ The type of constraints and their operation differs between software packages, but in **general terms constraints** override the duration and logic-driven CPM calculations.
 - ❖ This makes **constraints a powerful and potentially dangerous tool**.
 - ✓ When **constraints** are applied to the CPM schedule, there is a **significant risk** that the schedule will **report misleading**
 1. Start and finish dates,
 2. Float, and
 3. Criticality.

Restraints or constraints

❑ The **first choice** should be to **avoid** the use of constraints,

but **if used**, they should be **used sparingly** and
with **caution and understanding** of the **effect** they are having on the
underlying CPM calculations.

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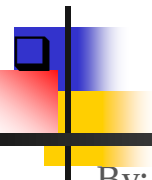
Network format

- ❑ A **horizontal diagram format** has become standard in the construction industry.
- ❑ The general synthesis of a network is from **start to finish**, from **project beginning** on the left to project completion **on the right**.
- ❑ The **sequential relationship** of one activity to another is **designated by the dependency** lines between them.

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Production planning

- ☐ Planning team
- ☐ Reengineering the project
- ☐ Planning for production
- ☐ Support planning
- ☐ Technical problems
- ☐ Personnel planning
- ☐ Safety planning
- ☐ Planning for quality
- ☐ Material ordering and expediting
- ☐ Material handling, storage, and protection
- ☐ Equipment planning



PROJECT SCHEDULING CONCEPTS

Introduction

- ❑ “Project Planning,” dealt with the **network diagram**.
 - ❖ Once this network diagram has **been developed**, the **time management** system enters the **next phase**: that of work scheduling.
- ❑ **Time relating** to overall project construction duration or the time required to complete individual activities has not been factored into the plan.
- ❑ This section is concerned with the **time scheduling** of construction projects.
- ❑ **Once** calculations have established the **time-based characteristics** of the project and each activity,
subsequent section will apply this knowledge to manage and control the project.

Scheduling procedure

❑ The following **eight steps** are offered as a procedural guide:

1. Estimate the time required to carry out each network activity.
2. Compute the time period required for the overall project completion using these time estimates.
3. Establish time intervals within which each activity must start and finish to satisfy the completion date requirement.
4. Identify those activities whose expedient execution is crucial to timely project completion.

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Scheduling procedure

❑ The following **eight steps** are offered as a procedural guide:

5. Shorten the project duration at the least possible cost if the project completion date will not meet the contract or other requirements.
6. Adjust the start and finish times of selected activities to minimize resource conflicts and smooth out demands for manpower and equipment using surplus or float times that most activities possess.
7. Make a working project schedule that shows anticipated calendar dates for the start and finish of each network activity.
8. Record the assumptions made and the plan's vital boundary conditions. These will become an integral aspect of the completed baseline project schedule.

Scheduling procedure

❑ This section discusses the **first four steps** just described.

The **remainder** are presented in **subsequent sections**.

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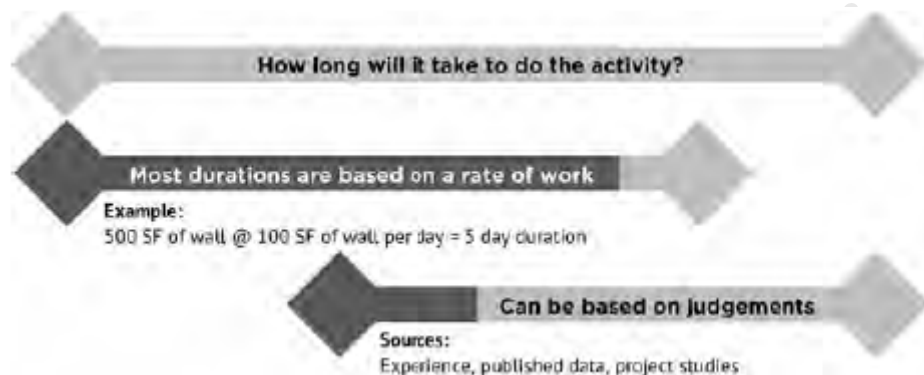
Activity times

- ☐ CPM customarily uses a **single time estimate** for each network activity.
- ☐ In **construction**, each activity is “**deterministic**” in the sense that **similar or identical work** has been **performed many times** before.
- ☐ **Such prior experience** enables the contractor to estimate with **reasonable accuracy** the time required to carry out each job operation.
- ☐ In the **construction industry**, activity durations are customarily expressed in terms of working days,
although other time units, such as hours, shifts, or calendar weeks, are sometimes used.

Activity times

- ❑ Durations are usually shown as **days**

but depending on the requirements of the project, an activity can be shown in **hours** for very time-sensitive applications or **weeks/months** during the conceptual stage.



Activity times

Once a time unit is selected, it must be used consistently throughout the network.

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Activity times – Rules for estimating

❑ **Six important rules** apply to the estimation of activity durations:

1. Evaluate activities one at a time, independently of all others
2. For each activity, assume a normal level of manpower and/or equipment
3. If time units of working days are being used, assume a normal workday
4. Concentrate on estimating the duration of the individual activity and ignore all other time considerations.
5. Use consistent time units throughout.
6. Assume normal weather conditions in estimating the duration needed to accomplish each activity.

Time contingency

- ❑ In most cases, though, a **contingency allowance** cannot be applied to individual activities to account for general project delays,
such as those caused by fires, accidents, equipment breakdowns, labor problems, late material deliveries, damage to material shipments, unanticipated site difficulties, and the like.
- ❑ Often, it is **impossible to predict** which activities may be affected and by how much.
- ❑ As a result, a **general allowance** for such time contingencies **normally is added** to the overall project duration or at the end of specific construction sequences.

Floats

total float

The amount of leeway available to start or complete an individual schedule activity before it affects the planned project completion.

Early start (ES) This is the earliest possible time that an activity can start according to the relationships associated with the activity.

Early finish (EF) This is the earliest time that an activity can finish given its allocated duration.

Late finish (LF) This is the latest time that an activity can finish without delaying the project's completion as planned.

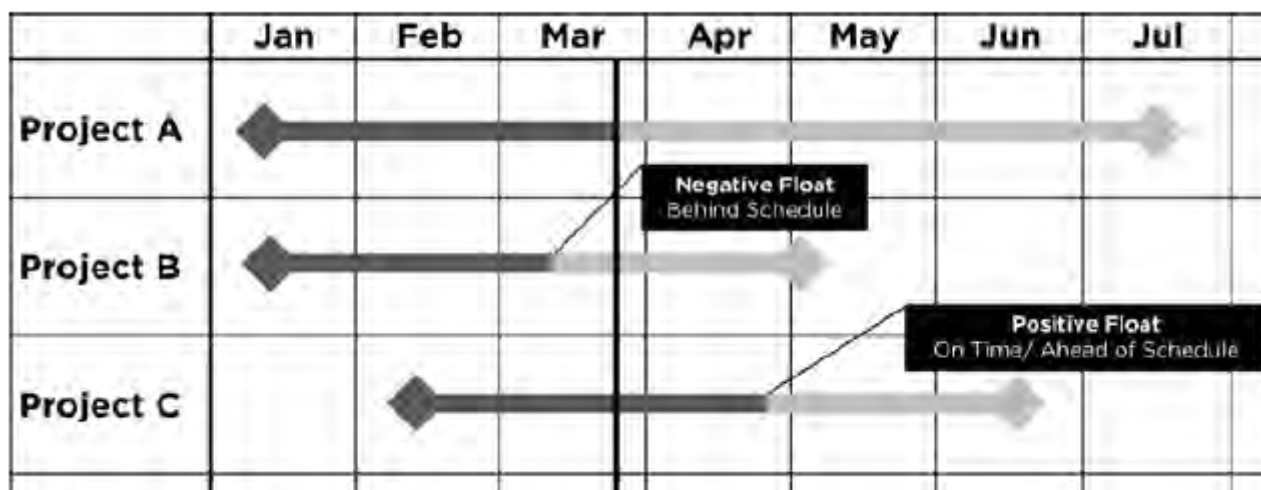
Late start (LS) This is the latest time that an activity can start without delaying the project's completion as planned.

Total float (TF) This is the amount of time an activity can be delayed before it impacts the project's completion as planned. Total float also allows an activity to exceed its planned duration without becoming critical if its completion remains within its total float allowance.

Free float (FF) This is the amount of time each activity can be delayed before it impacts the successor start date.

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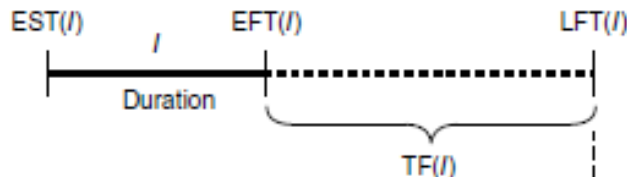
Floats



Floats

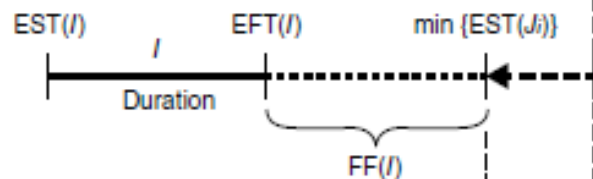
Total Float (TF)

$TF(I) = LFT(I) - EFT(I)$
 $= LST(I) - EST(I)$
 where I is current activity



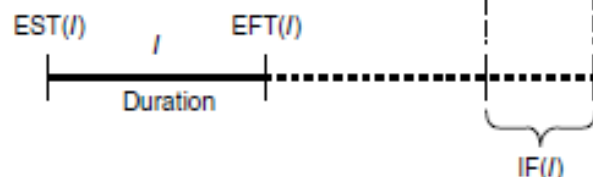
Free Float (FF)

$FF(I) = \min \{EST(J_i)\} - EFT(I)$
 where I is in its earliest position
 and J_i are all successors of I



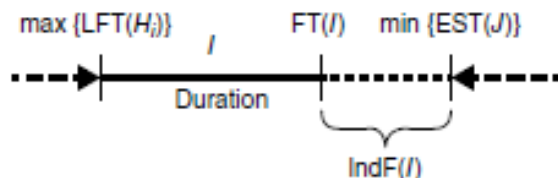
Interfering Float (IF)

$IF(I) = TF(I) - FF(I)$
 where I is current activity



Independent Float (IndF)

$IndF(I) = \min \{EST(J_i)\} -$
 $DUR(I) - \max \{LFT(H_i)\}$
 where H_i are all predecessors of I
 and J_i are all successors of I



Floats – Interfering float

$$IF(I) = TF(I) - FF(I)$$

The interfering float for activity C is:

$$IF(C) = TF(C) - FF(C) = 3 - 0 = 3$$

This implies that although three days of delay can occur on activity C without impacting the total project duration, each day of IF used in conjunction with activity C will “interfere” with the float available for the following activities.

Total Float (TF)

$TF(I) = LFT(I) - EF(I)$
 $= LST(I) - EST(I)$
 where I is current activity

Free Float (FF)

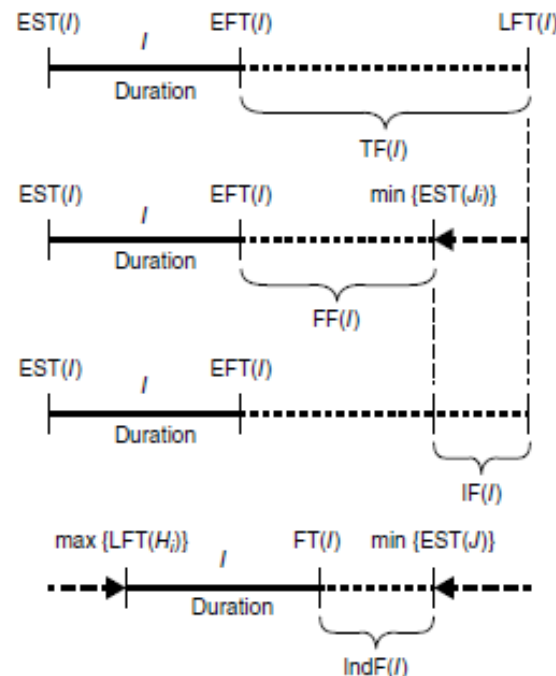
$FF(I) = \min \{EST(J_i)\} - EFT(I)$
 where I is in its earliest position
 and J_i are all successors of I

Interfering Float (IF)

$IF(I) = TF(I) - FF(I)$
 where I is current activity

Independent Float (IndF)

$IndF(I) = \min \{EST(J_i)\} -$
 $DUR(I) - \max \{LFT(H_i)\}$
 where H_i are all predecessors of I
 and J_i are all successors of I



Floats – Independent float

- ❑ The **duration itself** is subtracted to give just the **remaining flexibility**.

- ❑ In other words, this is a “**worst case**” where **activities before the current one** are delayed, **but following ones** still want to start as early as possible.

- ❑ In some cases, the **independent float** can even be negative.

Total Float (TF)

$TF(I) = LFT(I) - EFT(I)$
 $= LST(I) - EST(I)$
 where I is current activity

Free Float (FF)

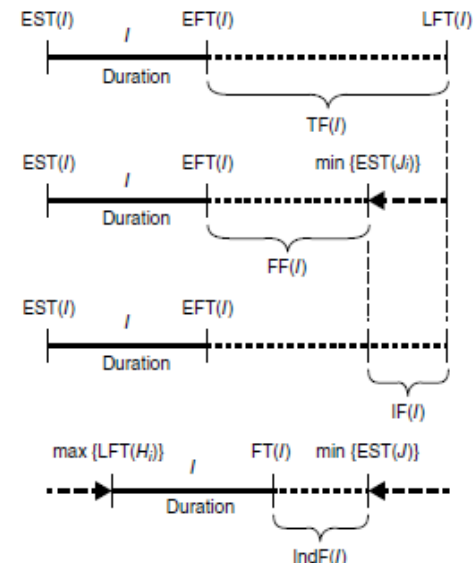
$FF(I) = \min \{EST(J_i)\} - EFT(I)$
 where I is in its earliest position
 and J_i are all successors of I

Interfering Float (IF)

$IF(I) = TF(I) - FF(I)$
 where I is current activity

Independent Float (IndF)

$IndF(I) = \min \{EST(J_i)\} -$
 $DUR(I) - \max \{LFT(H_i)\}$
 where H_i are all predecessors of I
 and J_i are all successors of I



Floats

As a practical matter the two floats that are of greatest interest are the total float and the free float.

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Critical path

- ❑ One of the **reasons** that the Precedence diagramming method (PDM) works so **well in construction** is because it allows you to **calculate the critical path**.
- ❑ The **critical path** is the **continuous chain of activities** with the longest overall duration—or, more simply, the critical path is the **project duration**.
- ❑ Any **delay in any activity** along the critical path may result in a **delay in the overall project**.

*If you are a **construction manager or superintendent** trying to meet your schedule targets, then it is pretty important for you to know which activities will impact the outcome most significantly so you can focus your attention there.*

Critical path

NOTE

The critical path can change throughout the duration of a project. Activities that possessed a lot of total float at the beginning of the project can become critical if they are delayed too much and exceed their total float. This is why it is very important to monitor and track all activities in the network, not just the critical ones.

Activity time information

Activity (Bold type denotes critical activities) (1)	Activity Number (2)	Activity Arrow (3)	Duration (Working Days) (4)	Earliest		Latest		Float	
				Start (ES) (5)	Finish (EF) (6)	Start (LS) (7)	Finish (LF) (8)	Total (TF) (9)	Free (FF) (10)
Start	0		0	0	0	0	0	0	0
Prepare & approve S/D abutment & deck rebar	10	10-50	10	0	10	0	10	0	0
Prepare & approve S/D footing rebar	20	10-60	5	0	5	9	14	9	0
Order & deliver piles	30	10-70	15	0	15	3	18	3	0
Move in	40	10-20	3	0	3	12	15	12	0
Prepare & approve S/D girders	50	10-40	10	0	10	8	18	8	0
Fabricate & deliver abutment & deck rebar	60	50-160	15	10	25	10	25	0	0
Fabricate & deliver footing rebar	70	60-100	7	5	12	14	21	9	6
Prefabricate abutment forms	80	20-160	3	3	6	22	25	19	19
Excavate abutment #1	90	20-30	3	3	6	15	18	12	0
Mobilize pile-driving rig	100	20-70	2	3	5	16	18	13	10
Drive piles-abutment #1	110	70-80	3	15	18	18	21	3	0
Excavate abutment #2	120	30-90	2	6	8	19	21	13	10
Forms & rebar footing #1	130	100-110	2	18	20	21	23	3	0
Drive piles abutment #2	140	90-140	3	18	21	21	24	3	0
Pour footing #1	150	110-120	1	20	21	23	24	3	0
Demobilize pile-driving rig	160	140-160	1	21	22	24	25	3	3
Strip footing #1	170	120-130	1	21	22	24	25	3	0
Forms & rebar abutment #1	180	160-180	4	25	29	25	29	0	0
Forms & rebar footing #2	190	150-170	2	22	24	30	32	8	0
Pour abutment #1	200	180-200	2	29	31	29	31	0	0
Pour footing #2	210	170-190	1	24	25	32	33	8	0
Strip & cure abutment #1	220	200-210	3	31	34	31	34	0	0
Strip footing #2	230	190-220	1	25	26	33	34	8	8
Forms & rebar abutment #2	240	220-230	4	34	38	34	38	0	0
Pour abutment #2	250	230-240	2	38	40	38	40	0	0
Fabricate & deliver girders	260	40-260	25	10	35	18	43	8	8
Rub concrete abutment #1	270	210-300	3	34	37	52	55	18	18
Backfill abutment #1	280	210-260	3	34	37	40	43	6	6
Strip & cure abutment #2	290	240-250	3	40	43	40	43	0	0
Rub concrete abutment #2	300	250-300	3	43	46	52	55	9	9
Backfill abutment #2	310	250-280	3	43	46	46	49	3	3
Set girders	320	260-270	2	43	45	43	45	0	0
Deck forms & rebar	330	270-280	4	45	49	45	49	0	0
Pour & cure deck	340	280-290	3	49	52	49	52	0	0
Strip deck	350	290-300	3	52	55	52	55	0	0
Guardrails	360	300-310	3	55	58	57	60	2	2
Paint	370	300-320	5	55	60	55	60	0	0
Saw joints	380	290-320	1	52	53	59	60	7	7
Cleanup	390	320-330	3	60	63	60	63	0	0
Final inspection	400	330-340	1	63	64	63	64	0	0
Contingency	410	340-350	6	64	70	64	70	0	0
Finish	420		0	70	70	70	70	0	0

Activity time information

1	2	3	4	5	6	7	8	9
Activity (BF type denotes critical activities)	Act #	Dur	ES	EF	LS	LF	TF	FF
Start	1	0	0	0	0	0	0	0
Mobilize	2	5	0	5	25	30	25	25
Utilities	3	45	0	45	80	125	20	80
Site Work	4	65	0	65	0	65	0	0
Site Electrical	5	15	65	80	205	220	140	140
Site Paving, Start	6	45	65	110	125	170	60	50
Site Paving, Finish	7	20	160	180	170	190	10	0
Irrigation	8	15	180	195	190	205	0	10
Landscape	9	15	195	200	205	220	10	10
Drilled Piers	10	10	20	30	20	30	0	0
Grade Beams & Slabs	11	30	30	60	30	60	0	0
Structural Erection	12	15	60	75	60	75	0	0
Miscellaneous Steel	13	20	75	95	125	145	50	10
Roofing	14	20	75	95	85	105	10	0
Framing	15	30	75	105	75	105	0	0
Dampproof	16	25	105	130	115	140	10	0
Masonry	17	30	130	160	140	170	10	0
Insulation	18	30	105	135	105	135	0	0
Gypsum Drywall	19	30	135	165	135	165	0	0
Aluminum Frames	20	30	105	135	120	150	15	0
Wood Doors	21	15	135	150	150	165	15	15
Storefront & Glazing	22	15	135	150	170	185	35	15
Plaster	23	20	105	120	145	165	40	40
Ceilings	24	20	165	185	185	205	20	0
Ceramic Tile	25	20	165	185	185	205	20	0
Flooring	26	15	185	200	205	220	20	20
Paint	27	35	165	200	165	200	0	0
Millwork	28	20	200	220	200	220	0	0
Signage	29	15	200	215	205	220	10	0
Toilet Partitions	30	15	185	200	205	220	20	20
Toilet Accessories	31	15	185	200	205	220	20	20
HVAC Rough-in	32	30	95	125	175	205	80	75
HVAC Finish	33	15	200	215	205	220	5	5
Plumbing under Slab	34	35	35	70	75	110	40	35
Plumbing in Partitions	35	25	105	130	110	135	5	5
Plumbing Fixtures	36	15	200	215	205	220	5	5
Fire Protection Rough-in	37	15	105	120	190	205	85	80
Fire Protection Finish	38	15	200	215	205	220	5	5
Electrical under Slab	39	30	35	65	75	105	40	40
Electrical in Partitions	40	30	105	135	105	135	0	0
Electrical Finish	41	50	150	200	170	220	20	20
Fire Alarm Rough-in	42	20	95	115	190	210	100	90
Fire Alarm Finish	43	10	205	215	210	220	5	5
Closeout	44	5	220	225	220	225	0	0

Early-start schedule

- ❑ After the **network calculations** have been completed,
the **resulting activity times** are used to prepare **various forms of calendar date** schedules that are used for project time management.
- ❑ One of these is a **schedule of activities** based on their early-start and finish times.
 - ❖ This time schedule is called an early-start schedule or a normal schedule.

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Early-start schedule

- ❑ Activity times obtained by **manual calculations** are expressed in terms of expired working days.
- ❑ For purposes of project monitoring and control,
it is necessary to **convert** these times to calendar dates on which each activity is **expected to start and finish**.
- ❑ This is done **easily** with the aid of a calendar on which the working days are numbered consecutively,
starting with number one on the anticipated start date and skipping weekends and holidays (July 5 and September 6 in our case).

Early-start schedule – Conversion calendar

June

Su	M	Tu	W	Th	F	Sa
		1	2	3	4	5
6	7	8	9	10	11	12
13	14 (1)	15 (2)	16 (3)	17 (4)	18 (5)	19
20	21 (6)	22 (7)	23 (8)	24 (9)	25 (10)	26
27	28 (11)	29 (12)	30 (13)			

July

Su	M	Tu	W	Th	F	Sa
				1 (14)	2 (15)	3
4	5	6 (16)	7 (17)	8 (18)	9 (19)	10
11	12 (20)	13 (21)	14 (22)	15 (23)	16 (24)	17
18	19 (25)	20 (26)	21 (27)	22 (28)	23 (29)	24
25	26 (30)	27 (31)	28 (32)	29 (33)	30 (34)	31

August

Su	M	Tu	W	Th	F	Sa
1	2 (35)	3 (36)	4 (37)	5 (38)	6 (39)	7
8	9 (40)	10 (41)	11 (42)	12 (43)	13 (44)	14
15	16 (45)	17 (46)	18 (47)	19 (48)	20 (49)	21
22	23 (50)	24 (51)	25 (52)	26 (53)	27 (54)	28
29	30 (55)	31 (56)				

September

Su	M	Tu	W	Th	F	Sa
			1 (57)	2 (58)	3 (59)	4
5	6	7 (60)	8 (61)	9 (62)	10 (63)	11
12	13 (64)	14 (65)	15 (66)	16 (67)	17 (68)	18
19	20 (69)	21 (70)	22	23	24	25
26	27	28	29	30		

Early-start schedule – Conversion calendar

December							January							February							March						
Su	M	Tu	W	Th	F	Sa	Su	M	Tu	W	Th	F	Sa	Su	M	Tu	W	Th	F	Sa	Su	M	Tu	W	Th	F	Sa
1	2	3	4	5	6	7				1	2	3	4							1							1
8	9	10	11	12	13	14	5	6	7	8	9	10	11	2	3	4	5	6	7	8	2	3	4	5	6	7	8
					0		14	15	16	17	18			34	35	36	37	38			54	55	56	57	58		
15	16	17	18	19	20	21	12	13	14	15	16	17	18	9	10	11	12	13	14	15	9	10	11	12	13	14	15
	1	2	3	4	5		19	20	21	22	23	24	25								59	60	61	62	63		
22	23	24	25	26	27	28	19	20	21	22	23	24	25	16	17	18	19	20	21	22	16	17	18	19	20	21	22
	6	7	8	9			24	25	26	27	28			44	45	46	47	48			64	65	66	67	68		
29	30	31					26	27	28	29	30	31		23	24	25	26	27	28	29	23	24	25	26	27	28	29
	10	11					29	30	31	32	33			49	50	51	52	53			30	31					
																					74						

April							May							June							July						
Su	M	Tu	W	Th	F	Sa	Su	M	Tu	W	Th	F	Sa	Su	M	Tu	W	Th	F	Sa	Su	M	Tu	W	Th	F	Sa
		1	2	3	4	5				1	2	3		1	2	3	4	5	6	7			1	2	3	4	5
		75	76	77	78					97	98			118	119	120	121	122			139	140	141				
6	7	8	9	10	11	12	4	5	6	7	8	9	10	8	9	10	11	12	13	14	6	7	8	9	10	11	12
	79	80	81	82	83		99	100	101	102	103			123	124	125	126	127			142	143	144	145	146		
13	14	15	16	17	18	19	11	12	13	14	15	16	17	15	16	17	18	19	20	21	13	14	15	16	17	18	19
	84	85	86	87	88		104	105	106	107	108			128	129	130	131	132			147	148	149	150	151		
20	21	22	23	24	25	26	18	19	20	21	22	23	24	22	23	24	25	26	27	28	20	21	22	23	24	25	26
	89	90	91	92	93		109	110	111	112	113			133	134	135	136	137			152	153	154	155	156		
27	28	29	30				25	26	27	28	29	30	31	29	30						27	28	29	30	31		
	94	95	96				114	115	116	117				138							157	158	159	160			

August							September							October							November						
Su	M	Tu	W	Th	F	Sa	Su	M	Tu	W	Th	F	Sa	Su	M	Tu	W	Th	F	Sa	Su	M	Tu	W	Th	F	Sa
					1	2		1	2	3	4	5	6			1	2	3	4							1	
					161					182	183	184	185								2	3	4	5	6	7	8
3	4	5	6	7	8	9	7	8	9	10	11	12	13	5	6	7	8	9	10	11							
	162	163	164	165	166		186	187	188	189	190			206	207	208	209	210			2	3	4	5	6	7	8
10	11	12	13	14	15	16	14	15	16	17	18	19	20	12	13	14	15	16	17	18	9	10	11	12	13	14	15
	167	168	169	170	171		191	192	193	194	195			211	212	213	214	215									
17	18	19	20	21	22	23	21	22	23	24	25	26	27	19	20	21	22	23	24	25	16	17	18	19	20	21	22
	172	173	174	175	176		196	197	198	199	200			216	217	218	219	220									
24	25	26	27	28	29	30	28	29	30					26	27	28	29	30	31		23	24	25	26	27	28	29
	177	178	179	180	181		201	202						221	222	223	224	225			30						
31																											

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Tabular time schedules

- ☐ **When** the computed activity times are **converted to calendar dates**, this schedule information often is **presented in a tabular format**.
- ☐ **Not only** is this sort of operational schedule useful to the contractor;
it also can be used to satisfy the usual contract requirement of providing the owner
and architect-engineer
with a **projected timetable of construction operations**.

Tabular time schedules

The table in this Figure is the **early-start schedule** for the highway bridge, with the activities listed in the **order of their starting dates**.

Project Calendar				
Activity (Bold type denotes critical activities)	Activity Number	Duration (Working Days)	Scheduled Starting Date A.M.	Scheduled Completion Date P.M.
Prepare & approve S/D, abutment & deck rebar	10	10	June-14	June-25
Prepare & approve S/D, footing rebar	20	5	June-14	June-18
Order & deliver piles	30	15	June-14	July-2
Move in	40	3	June-14	June-16
Prepare & approve S/D, girders	50	10	June-14	June-25
Prefabricate abutment forms	80	3	June-17	June-21
Excavate abutment #1	90	3	June-17	June-21
Mobilize pile-driving rig	100	2	June-17	June-18
Fabricate & deliver footing rebar	70	7	June-21	June-29
Excavate abutment #2	120	2	June-22	June-23
Fabricate & deliver abutment & deck rebar	60	15	June-28	July-19
Fabricate & deliver girders	260	25	June-28	August-2
Drive piles, abutment #1	110	3	July-6	July-8
Forms & rebar, footing #1	130	2	July-9	July-12
Drive piles, abutment #2	140	3	July-9	July-13
Pour footing #1	150	1	July-13	July-13
Demobilize pile-driving rig	160	1	July-14	July-14
Strip footing #1	170	1	July-14	July-14
Forms & rebar, footing #2	190	2	July-15	July-16
Pour footing #2	210	1	July-19	July-19
Forms & rebar, abutment #1	180	4	July-20	July-23
Strip footing #2	230	1	December-21	July-20
Pour abutment #1	200	2	July-26	July-27
Strip & cure, abutment #1	220	3	July-28	July-30
Forms & rebar, abutment #2	240	4	August-2	August-5
Rub concrete, abutment #1	270	3	August-2	August-4
Backfill abutment #1	280	3	August-2	August-14
Pour abutment #2	250	2	August-6	August-9
Strip & cure, abutment #2	290	3	August-10	August-12
Hub concrete, abutment #2	300	3	August-13	August-17
Backfill abutment #2	310	3	August-13	August-17
Set girders	320	2	August-13	August-16
Deck forms & rebar	330	4	August-17	August-20
Pour & cure deck	340	3	August-23	August-25
Strip deck	350	3	August-26	August-30
Saw joints	380	1	August-26	August-26
Guardrails	360	3	August-31	September-2
Paint	370	5	August-31	September-7
Cleanup	390	3	September-8	September-10
Final inspection	400	1	September-13	September-13
Contingency	410	6	September-14	September-21

Tabular time schedules

This Figure provides the **comparable information** for the commercial building.

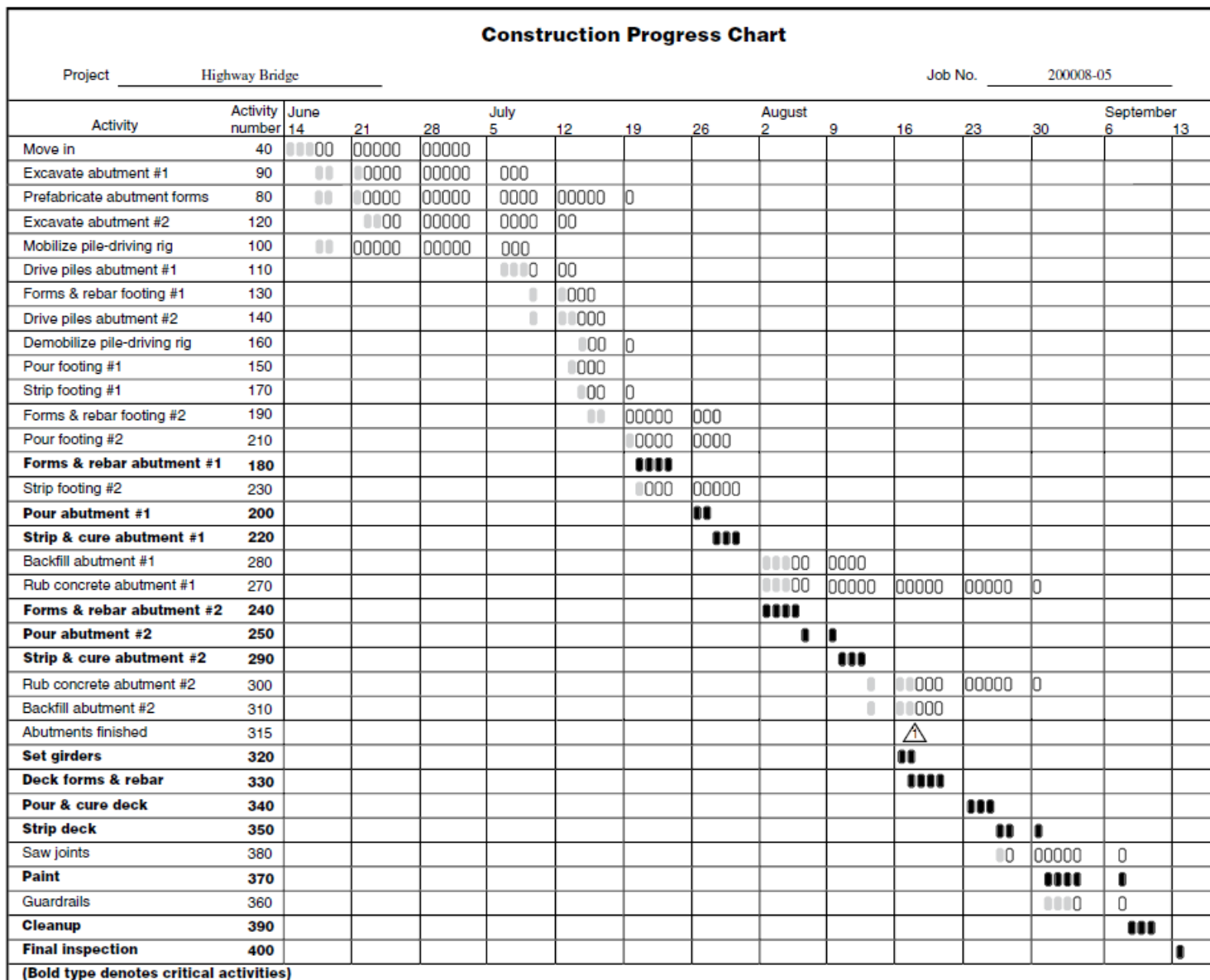
These calendar dates often are referred to as **scheduled or expected dates**.

ID	Task Name	Start	Finish	Late Start	Late Finish	Free Slack	Total Slack
1	Start	Mon 12/16/13	Mon 12/16/13	Mon 12/16/13	Mon 12/16/13	0 days	0 days
2	Mobilize	Mon 12/16/13	Fri 12/20/13	Mon 12/8/14	Fri 12/12/14	60 days	255 days
3	Utilities	Mon 12/16/13	Tue 2/18/14	Wed 4/9/14	Wed 6/11/14	20 days	80 days
4	Site Work	Mon 12/16/13	Tue 3/18/14	Mon 12/16/13	Tue 3/18/14	0 days	0 days
5	Site Electrical	Wed 3/19/14	Tue 4/8/14	Mon 10/6/14	Fri 10/24/14	140 days	140 days
6	Site Paving, Start	Wed 3/19/14	Tue 5/20/14	Thu 6/12/14	Thu 8/14/14	50 days	60 days
7	Site Paving, Finish	Fri 8/1/14	Thu 8/28/14	Fri 8/15/14	Fri 9/12/14	0 days	10 days
8	Irrigation	Fri 8/29/14	Fri 9/19/14	Mon 9/15/14	Fri 10/3/14	0 days	10 days
9	Landscape	Mon 9/22/14	Fri 10/10/14	Mon 10/6/14	Fri 10/24/14	10 days	10 days
10	Drilled Piers	Wed 1/15/14	Tue 1/28/14	Wed 1/15/14	Tue 1/28/14	0 days	0 days
11	Grade Beams & Slabs	Wed 1/29/14	Tue 3/11/14	Wed 1/29/14	Tue 3/11/14	0 days	0 days
12	Structural Erection	Wed 3/12/14	Tue 4/1/14	Wed 3/12/14	Tue 4/1/14	0 days	0 days
13	Miscellaneous Steel	Wed 4/2/14	Tue 4/29/14	Thu 6/12/14	Thu 7/10/14	10 days	50 days
14	Roofing	Wed 4/2/14	Tue 4/29/14	Wed 4/16/14	Tue 5/13/14	0 days	10 days
15	Framing	Wed 4/2/14	Tue 5/13/14	Wed 4/2/14	Tue 5/13/14	0 days	0 days
16	Dampproof	Wed 5/14/14	Wed 6/18/14	Thu 5/29/14	Wed 7/2/14	0 days	10 days
17	Masonry	Thu 6/19/14	Thu 7/31/14	Thu 7/3/14	Thu 8/14/14	0 days	10 days
18	Insulation	Wed 5/14/14	Wed 6/25/14	Wed 5/14/14	Wed 6/25/14	0 days	0 days
19	Gypsum Drywall	Thu 6/26/14	Thu 8/7/14	Thu 6/26/14	Thu 8/7/14	0 days	0 days
20	Aluminum Frames	Wed 5/14/14	Wed 6/25/14	Thu 6/5/14	Thu 7/17/14	0 days	15 days
21	Wood Doors	Thu 6/26/14	Thu 7/17/14	Fri 7/18/14	Thu 8/7/14	15 days	15 days
22	Storefront, Glazing	Thu 6/26/14	Thu 7/17/14	Fri 8/15/14	Fri 9/5/14	15 days	35 days
23	Plaster	Wed 5/14/14	Wed 6/11/14	Fri 7/11/14	Thu 8/7/14	40 days	40 days
24	Ceilings	Fri 8/8/14	Fri 9/5/14	Mon 9/8/14	Fri 10/3/14	0 days	20 days
25	Ceramic Tile	Fri 8/8/14	Fri 9/5/14	Mon 9/8/14	Fri 10/3/14	0 days	20 days
26	Flooring	Mon 9/8/14	Fri 9/26/14	Mon 10/6/14	Fri 10/24/14	20 days	20 days
27	Paint	Fri 8/8/14	Fri 9/26/14	Fri 8/8/14	Fri 9/26/14	0 days	0 days
28	Millwork	Mon 9/29/14	Fri 10/24/14	Mon 9/29/14	Fri 10/24/14	0 days	0 days
29	Signage	Mon 9/29/14	Fri 10/17/14	Mon 10/13/14	Fri 10/31/14	0 days	10 days
30	Toilet Partitions	Mon 9/8/14	Fri 9/26/14	Mon 10/6/14	Fri 10/24/14	20 days	20 days
31	Toilet Accessories	Mon 9/8/14	Fri 9/26/14	Mon 10/6/14	Fri 10/24/14	20 days	20 days
32	HVAV Rough in	Wed 4/30/14	Wed 6/11/14	Fri 8/22/14	Fri 10/3/14	75 days	80 days
33	HVAC Finish	Mon 9/29/14	Fri 10/17/14	Mon 10/6/14	Fri 10/24/14	5 days	5 days
34	Plumbing, under Slab	Wed 2/5/14	Tue 3/25/14	Wed 4/2/14	Tue 5/20/14	35 days	40 days
35	Plumbing in Partitions	Wed 5/14/14	Wed 6/18/14	Wed 5/21/14	Wed 6/25/14	5 days	5 days
36	Plumbing Fixtures	Mon 9/29/14	Fri 10/17/14	Mon 10/6/14	Fri 10/24/14	5 days	5 days
37	Fire Protection Rough in	Wed 5/14/14	Wed 6/4/14	Mon 9/15/14	Fri 10/3/14	80 days	85 days
38	Fire Protection Finish	Mon 9/29/14	Fri 10/17/14	Mon 10/6/14	Fri 10/24/14	5 days	5 days
39	Electrical, under Slab	Wed 2/5/14	Tue 3/18/14	Wed 4/2/14	Tue 5/13/14	40 days	40 days
40	Electrical, RI Partitions	Wed 5/14/14	Wed 6/25/14	Wed 5/14/14	Wed 6/25/14	0 days	0 days
41	Electrical Finish	Fri 7/18/14	Fri 9/26/14	Fri 8/15/14	Fri 10/24/14	20 days	20 days
42	Fire Alarm Rough in	Wed 4/30/14	Wed 5/28/14	Mon 9/22/14	Fri 10/17/14	90 days	100 days
43	Fire Alarm Finish	Mon 10/6/14	Fri 10/17/14	Mon 10/13/14	Fri 10/24/14	5 days	5 days
44	Closeout	Mon 10/27/14	Fri 10/31/14	Mon 10/27/14	Fri 10/31/14	0 days	0 days

Milestone

- ☐ **Milestones** are points in time that have been identified as being **important intermediate reference points** during the accomplishment of the work.
- ☐ **Milestone events** can include
 1. **Dates** imposed by the owner for finishing certain tasks
 2. **Target dates** set by the contractor for completing certain segments of the work
- ☐ On **large projects**, contractors frequently establish a series of milestones extending **throughout the project** and use these as reference **points for project monitoring**.

Bar charts



Resource management

- ❑ A **prerequisite** to **manpower management** is a detailed analysis of the **labor requirements** necessary to meet the project schedule.
- ❑ Using this information, the **project manager** may then **compare these needs** with an estimate of available manpower
to **determine** whether the project schedule is generally **achievable**.
- ❑ Once this calculation has been performed and **no adjustment** to the overall job completion date appears **necessary**,
the **project manager** may then turn his attention to leveling out the peaks and valleys in labor demand.

Resource management – Tabular of labor requirements

□ Activity manpower needs

Activity Number	Activity	Duration	Pile-driverman	Carpenter	Laborer	Equipment Operator	Oiler	Iron Worker	Cement Mason	Truck Driver
40	Move in	3		3	4	2				4
80	Prefabricate abutment forms	3		3	3					
90	Excavate abutment #1 days 1 & 2 day 3	3			3	1				
100	Mobilize pile-driving rig	2	3		7	1				2
110	Drive piles, abutment #1	3	4	1	2	2	1			
120	Excavate abutment #2 day 1 day 2	2			3	1				
130	Forms & rebar, footing #1	2		1	1					
140	Drive piles, abutment #2	3	4	1	2	1	1			
150	Pour footing #1	1		2	4	1	1		1	
160	Demobilize pile-driving rig	1	3		2	2	1			2
170	Strip footing #1	1			2					
180	Forms & rebar, abutment #1	4		3	3					
190	Forms & rebar, footing #2	2		1	1					
200	Pour abutment #1	2		2	6	1	1		1	
210	Pour footing #2	1		2	4	1	1		1	
220	Strip & cure, abutment #1 day 1	3		3	6					
230	Strip footing #2	1			2					
240	Forms & rebar, abutment #2	4		3	3					
250	Pour abutment #2	2		2	6	1	1		1	
270	Rub concrete, abutment #1	3			1				2	
280	Backfill abutment #1	3			3					
290	Strip & cure, abutment #2 day 1	3		3	6					
300	Rub concrete, abutment #2	3			1				2	
310	Backfill abutment #2	3			3					
320	Set girders	2			4	1	1	4		
330	Deck forms & rebar	4		3	2					
340	Pour & cure deck day 1	3		2	6	1	1		4	
350	Strip deck	3			3					
360	Guardrails	3			1			2		
370	Paint	5								
380	Saw joints	1			1					
390	Cleanup days 1 & 2 day 3	3			7	1	1			2

(Bold type denotes critical activities)

Resource management – Project labor summary

☐ Daily manpower compilation

Craft	Working Days																														
	1	2	3	4	5	6	7	8	9	10	11	12	13	14	15	16	17	18	19	20	21	22	23	24	25	26	27	28	29	30	
Piledrivers				3	3											4	4	4	4	4	4	4	3								
Carpenters	3	3	3	3	3	3										1	1	1	2	2	3		1	1	2	3	3	3	3	2	
Laborers	4	4	4	8	8	10	3	7								2	2	2	3	3	6	4	1	1	6	8	6	6	6	8	
Equipment operators	2	2	2	3	3	1	1	1								1	1	1	1	1	2	2		1						1	
Oilers						1	1									1	1	1	1	1	2	1		1						1	
Iron workers																															
Cement masons																					1			1						1	
Truck drivers	4	4	4	2	2																1										
	14	15	16	17	18	21	22	23	24	25	28	29	30		1	2	6	7	8	9	12	13	14	15	16	19	20	21	22	23	26
	June															July															

Craft	Working Days																															
	1	2	3	4	5	6	7	8	9	10	11	12	13	14	15	16	17	18	19	20	21	22	23	24	25	26	27	28	29	30		
Piledrivers				3	3											4	4	4	4	4	4	3										
Carpenters	3	3	3	3	3	3										1	1	1	2	2	3		1	1	2			3	3	3	3	2
Laborers	4	4	4	8	8	10	3	7								2	2	2	3	3	6	4	1	1	6			8	6	6	6	8
Equipment operators	2	2	2	3	3	1	1	1								1	1	1	1	1	2	2		1							1	
Oilers						1	1									1	1	1	1	1	2	1		1							1	
Iron workers																																
Cement masons																					1			1							1	
Truck drivers	4	4	4	2	2																	1										
	14	15	16	17	18	21	22	23	24	25	28	29	30	1	2	6	7	8	9	12	13	14	15	16	19	20	21	22	23	26		
	June															July																

MANAGING TIME

Introduction

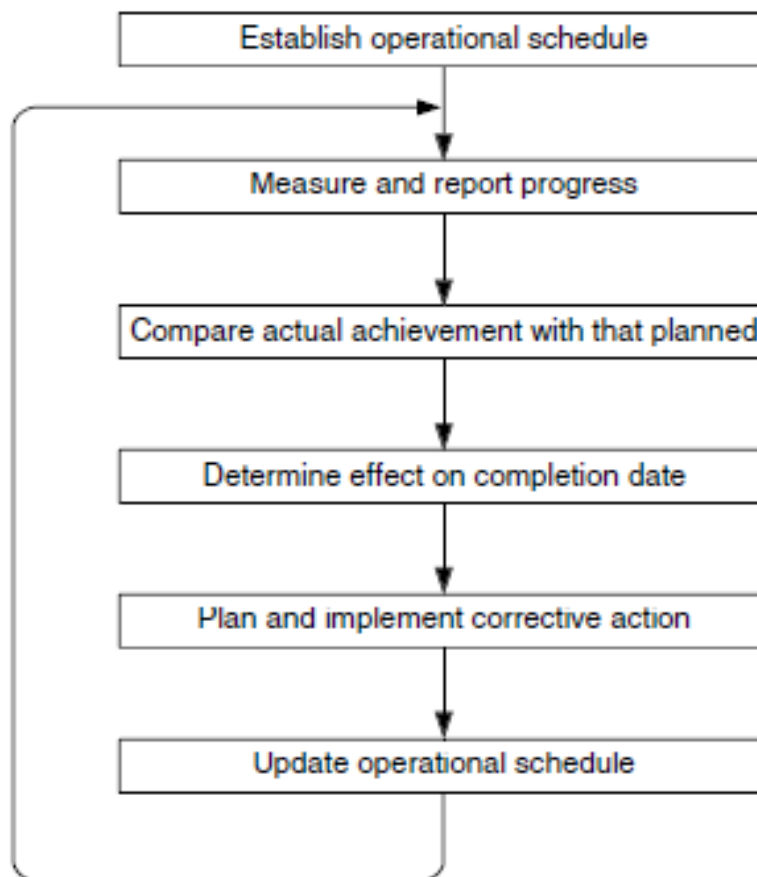
- ❑ Once the initial schedule is developed, it **represents a powerful tool** that can be **used in managing various aspects** of the project, including time, resources, production, and cost.
- ❑ As the project progresses and the project management team recognizes more of the details that affect the **construction process**, the **schedule will be modified** to evolve with the project.

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Introduction

- ❑ This section concentrates on using the schedule to **manage** the time required to execute the construction processes.
- ❑ It **begins** by
 1. Considering the project as a whole,
 2. Determining how to shorten the overall project schedule, and
 3. Looking at the cost trade-offs of expediting the project.
- ❑ It then focuses on **current or upcoming parts** of the project with the objective of managing the project components **more effectively**.

Time management cycle



Time schedule adjustment

- ☐ The **start or finish dates** of major job elements often must be improved to satisfy established time constraints or commitments.
- ☐ Milestones, network interfaces, and final completion are **common examples of key events**
that sometimes must be rescheduled to earlier dates.
- ☐ **Such schedule advances** are accomplished in practice by **performing certain portions** of the work in **shorter times** than had originally been **allocated to them**.

Time schedule adjustment – Guides

1. Restudy of critical activity durations
2. Restudy of project plan
3. Critical activities in parallel
4. Subdivision of critical activities
5. Subcontracting

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Time schedule adjustment – Shortening the longest path

Expediting Action	Time Reduction (Working days)	Direct Cost of Expediting
A Prefabricate two sets of abutment forms. Start placing Forms & rebar, abutment #2 (activity 240) directly after Strip footing #2 (activity 230) <u>Computations</u> One set of forms as estimated (Figure 3.6) Labor \$5,144 Material \$2,153 \$7,297 Two sets of forms Material Plyform: 10% waste, 1 use, 70% salvage 3620 (1.10)(\$1.05)(.30) = \$1,254 Lumber: 1.44 bf per sf, 1 use, 70% salvage 3620 (1.44)(\$0.85)(0.30) = \$1,329 Labor 3620 (\$1.96) + 45% indirect = \$10,288 \$12,872 Cost of expediting = \$12,872 - \$7,297 = \$5,575	6 (logic change)	\$5,575
B Steel fabricator agrees to work overtime and give abutment rebar special handling. Deliver abutment & deck rebar (activity 60) reduced from 15 to 11 days.	4	\$2,376 (quoted by rebar vendor)
C Expedite Pour abutment #1 (activity 200) by bringing in an additional crane, hiring two more laborers, and working the concrete crew 2 hours overtime. Duration reduced from 2 days to 1 day. <u>Computations</u> Pour abutment #1 as estimated (Figure 3.6) Labor \$12,269/2 = \$6,134 Equipment \$3,744/2 = \$1,872 \$8,006 Expedited Pour abutment #1 (10 hours) Labor Regular crew 284 x 10 x 1.35 = \$3,834 Extra laborers and operator (\$44 + \$33) x 10 x 1.30 \$1,001 Overtime premium (\$284 + \$77) x 2 x 0.5 x 1.35 \$487 Equipment Cost of two cranes, etc. \$2,500 Extra crane, in and out \$605 \$8,427 Cost of expediting = \$8,427 - \$8,006 = \$422	1	\$422
D Expedite Pour abutment #2 (activity 250) in the same way as abutment #1.	1	\$422
E Expedite Strip deck forms (activity 350) by hiring two more laborers. Duration reduced from 3 days to 2 days.	1	\$202 (not shown but similar to previous calculations)

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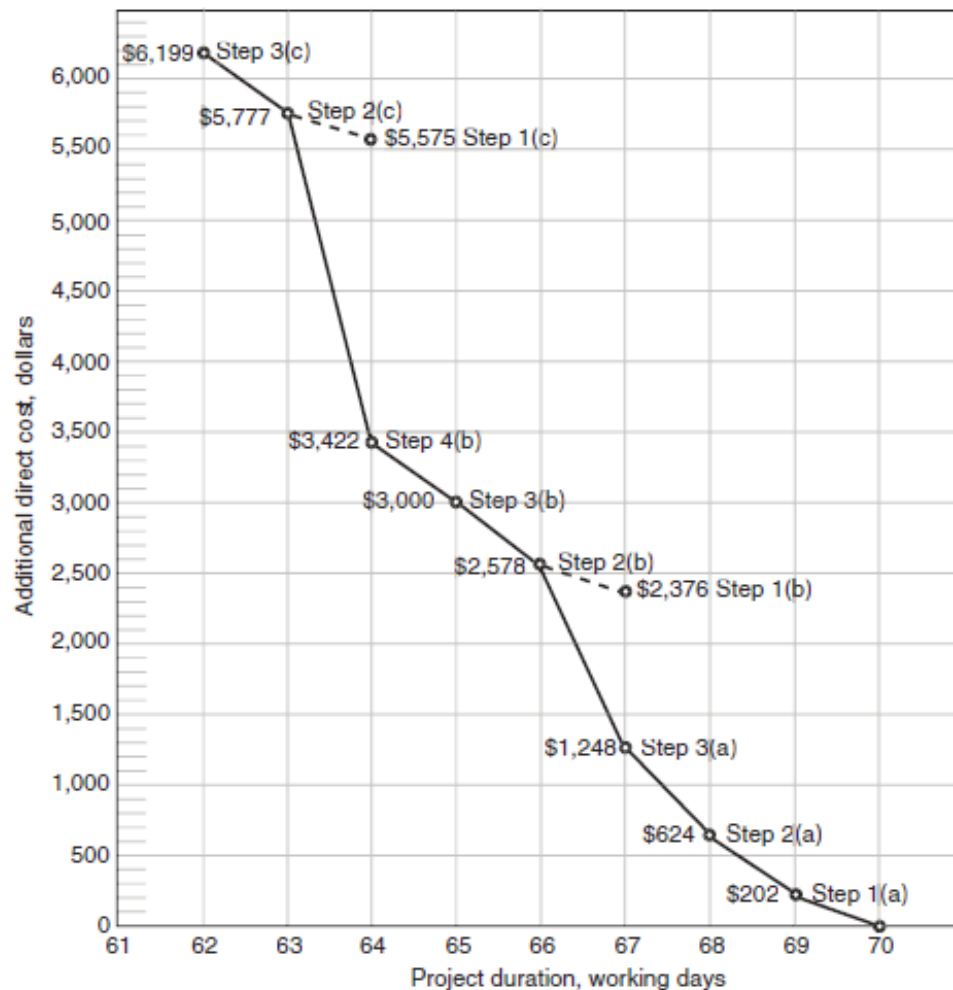
Time schedule adjustment – Shortening the longest path

☐ Least-cost expediting

Step	Project Duration (Working days)	Expediting Action (from Figure 7.4)	Critical Activity Shortened	New Critical Path	Add'l. Direct Cost	Cumulative Direct Cost
(a)						
*1	69	E	350	Physical limit = 1 Logical limit = 7 No	\$202	\$202
*2	68	C	200	Physical limit = 1 Logical limit = 8 No	\$422	\$624
*3	67	D	250	Physical limit = 1 Logical limit = 6 No	\$422	\$1,248
(b)						
1	67	B	60	Physical limit = 4 Logical limit = 3 Yes	\$2,376	\$2,376
*2	66	E	350	Physical limit = 1 Logical limit = 7 No	\$202	\$2,578
*3	65	C	200	Physical limit = 1 Logical limit = 8 No	\$422	\$3,000
*4	64	D	250	Physical limit = 1 Logical limit = 6 No	\$422	\$3,422
(c)						
1	64	A	Logic change	Logical limit = 6 Yes	\$5,575	\$5,575
*2	63	E	350	Physical limit = 1 Logical limit = 7 No	\$202	\$5,777
*3	62	C	200	Physical limit = 1 Logical limit = 8 No	\$422	\$6,199
*Optimal time-cost relationship						

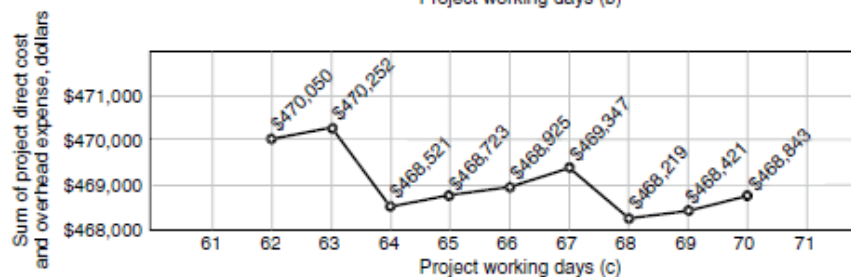
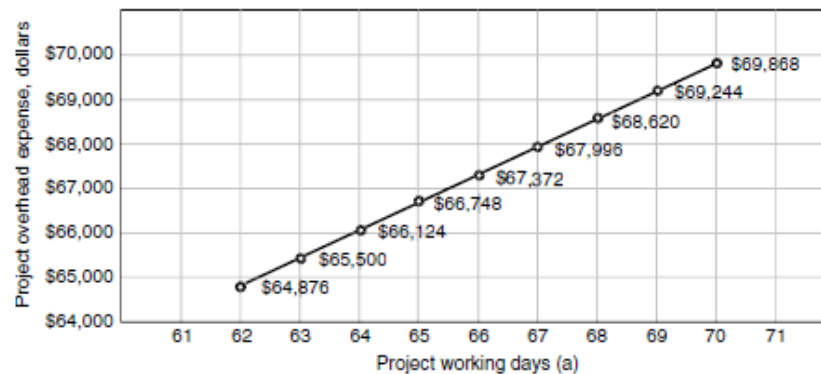
Time schedule adjustment – Shortening the longest path

❑ Cost of expediting

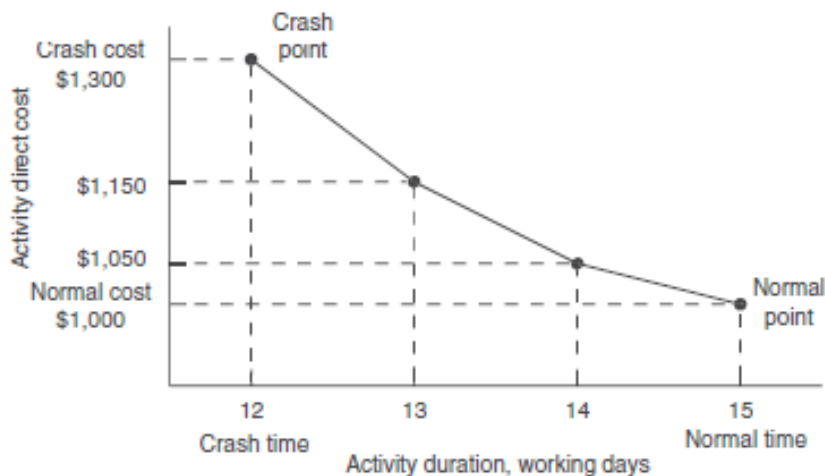


Time schedule adjustment – Shortening the longest path

□ Variation of costs with duration



Time schedule adjustment – Shortening the longest path



Time schedule adjustment – Shortening the longest path

☐ Expedited schedule

Activity (Bold type denotes critical activity) (1)	Activity Number (2)	Duration (Working Days) (3)	Earliest		Latest		Float	
			Start (ES) (4)	Finish (EF) (5)	Start (LS) (6)	Finish (LF) (7)	Total (TF) (8)	Free (FF) (9)
Start	0	0	0	0	0	0	0	0
Prepare & approve S/D abutment & deck rebar	10	10	0	10	0	10	0	0
Prepare & approve S/D footing rebar	20	5	0	5	7	12	7	0
Order & deliver piles	30	15	0	15	1	16	1	0
Move in	40	3	0	3	10	13	10	0
Prepare & approve S/D girders	50	10	0	10	1	11	1	0
Fabricate & deliver abutment & deck rebar	60	15	10	25	10	25	0	0
Fabricate & deliver footing rebar	70	7	5	12	12	19	7	6
Prefabricate abutment forms	80	6	3	9	19	25	16	16
Excavate abutment #1	90	3	3	6	13	16	10	0
Mobilize pile-driving rig	100	2	3	5	14	16	11	10
Drive piles abutment #1	110	3	15	18	16	19	1	0
Excavate abutment #2	120	2	6	8	18	20	12	10
Forms & rebar footing #1	130	2	18	20	19	21	1	0
Drive piles abutment #2	140	3	18	21	20	23	2	0
Pour footing #1	150	1	20	21	21	22	1	0
Demobilize pile-driving rig	160	1	21	22	24	25	3	3
Strip footing #1	170	1	21	22	22	23	1	0
Forms & rebar abutment #1	180	4	25	29	25	29	0	0
Forms & rebar abutment #2	190	2	22	24	23	25	1	0
Pour abutment #1	200	1	29	30	29	30	0	0
Pour footing #2	210	1	24	25	25	26	1	0
Strip & cure abutment #1	220	3	30	33	30	33	0	0
Strip footing #2	230	1	25	26	26	27	1	0
Forms & rebar abutment #2	240	4	26	30	27	31	1	0
Pour abutment #2	250	2	30	32	31	33	1	0
Fabricate & deliver girders	260	25	10	35	11	36	1	1
Rub concrete abutment #1	270	3	33	36	44	47	11	11
Backfill abutment #1	280	3	33	36	33	36	0	0
Strip & cure abutment #2	290	3	32	35	33	36	1	0
Rub concrete abutment #2	300	3	35	38	44	47	9	9
Backfill abutment #2	310	3	35	38	39	42	4	4
Set girders	320	2	36	38	36	38	0	0
Deck forms & rebar	330	4	38	42	38	42	0	0
Pour & cure deck	340	3	42	45	42	45	0	0
Strip deck	350	2	45	47	45	47	0	0
Guardrails	360	3	47	50	49	52	2	2
Paint	370	5	47	52	47	52	0	0
Saw joints	380	1	45	46	51	52	6	6
Cleanup	390	3	52	55	52	55	0	0
Final inspection	400	1	55	56	55	56	0	0
Contingency	410	6	56	62	56	62	0	0
Finish	420	0	62	62	62	62	0	0

Time schedule adjustment – Limitations

1. Physical limit of a critical activity
2. Logical limit of a critical activity
3. Logical limit of a network logic change
4. Shortening by a parallel critical path

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PROJECT SCHEDULING APPLICATIONS

Introduction

- ❑ Whereas **previous sections** focused more on tactical use of the schedule to manage **specific components** of the project, such as production, time, resources, and costs, **this section** will consider strategic scheduling applications as they relate to the overall project,
including consideration of the legal aspects of the schedule.
- ❑ **This section** begins by considering
 1. The role of the schedule and
 2. The variety of operational schedules available to the construction manager, which leads to a discussion of the ways in **which scheduling information** can be organized and can be presented.

Role of the schedule

❑ **All contracts** must have an **object**, usually relating to

1. The value of, and
2. The expectations of,

goods or services.

❑ **Most contracts** relate to an object that is palpable, physical, already exists, and is therefore easily defined.

- ❖ *For example, typically when a buyer and seller enter into a contract for the sale of an automobile, the automobile already exists.*
- ❖ *It can be seen, felt, examined, tested, and driven.*
- ❖ *To assure that the automobile will meet the buyer's needs, the buyer is expected to inspect the automobile diligently prior to entering into the contract.*

Role of the schedule

- ❑ **Both** process and final product definitions are needed
for a proper and **comprehensive understanding** of the **object** of the construction contract.
- ❑ **Both parties** must make every effort to **clearly communicate** their concept of the project at the time the **contract is drafted and signed**.
- ❑ **Failure by one** will **give the other the opportunity** to unilaterally add detail to ambiguous areas when conflicts arise.
- ❑ **Even in the simpler case** of the automobile, conflict often arises from an **incomplete understanding**.



Operational schedules

- ☐ Baseline schedule
- ☐ Schedule updates
- ☐ Revised schedules and recovery plans
- ☐ Short-term look-ahead schedule
- ☐ As-built schedule

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Operational schedules – Baseline schedule

Baseline Schedule

When the schedule calculated as described above is reviewed and found to be acceptable to the CM, owner, and design team, it should be considered the baseline against which progress is reported and compared. As the project progresses, changes may need to be made to reflect the current conditions, more detailed work descriptions, unanticipated events, delay recovery, and the inclusion of input by other interested parties. Schedules can be represented graphically using a Precedence Diagram Method (PDM) also known as Activity-on-Arrow Network (AON), but most are now commonly presented in the form of a Gantt Chart.

Operational schedules – Schedule updates

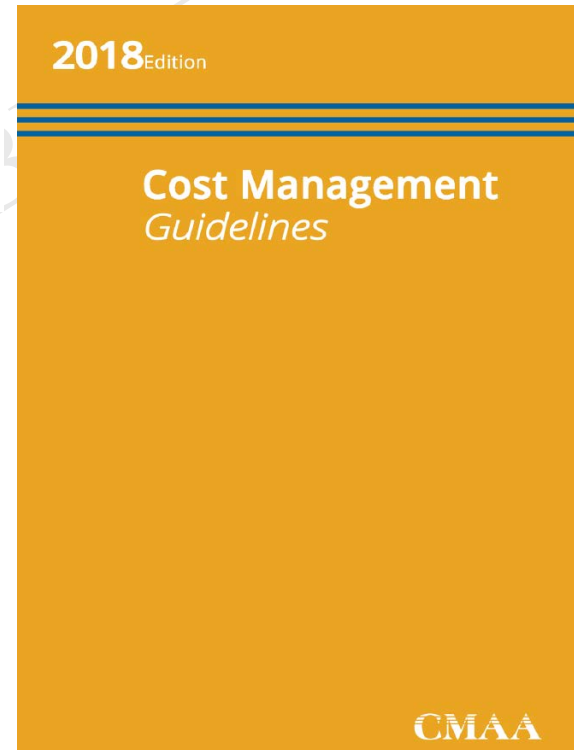
Schedule Updates – The frequency (usually monthly) of schedule updates and the allowable timeframe between the data or status date of the update and the submittal date should be defined in the contract documents. If the schedule is to be cost-loaded or made the basis for progress payments, this must also be established and appropriate procedures and protocols defined in the contract. The contract should also clearly distinguish between updates containing status-only (defined as the posting of progress information – actual start and finish dates, percentage of completion, and remaining duration) and logic revisions (significant changes in sequence or durations).



Operational schedules – Schedule updates

The contract should define the method for reporting progress on activities. Generally, progress can be reported as a percent complete of original duration or the number of days of remaining duration. Generally, cost-loaded schedules that are used for progress payments are updated using the percent complete method, with the remaining duration of activities calculated by the computer. Depending on the project, updates based on remaining duration may present a more accurate picture of schedule status, since the project manager, superintendent, foreman, and others tend to plan and forecast the remaining work in terms of days it will take to complete (remaining duration) rather than the percent of work that remains. Another possible option may be to disconnect percent complete from remaining duration and status percent complete for costs and remaining duration for time. In addition, if using earned value, updating time and cost separately provides more value from the metrics, since cost metrics (cost performance index – CPI) will not equal time metrics (schedule performance index – SPI) as it would if the software updates remaining duration by using percent complete. See *Cost Management Guidelines* for more details.

The contract should clearly address what should and should not be included in an update. Complex schedules often include imperfections, and minor changes are frequently required to keep these schedules accurate and useful. The CM may recommend that such minor changes be allowed as part of the updating process. The contract should state whether delay-related activities can be included in an update and, if so, the process by which such activities are to be incorporated. Significant (meaning "not minor," as discussed above) logic or duration revisions should be subject to CM and owner review and acceptance.



Operational schedules – Revised schedules and recovery plans

Revised Schedules and Recovery Plans – The contract should make clear the circumstances under which a contractor must submit a revised schedule or, when the project has fallen behind, a recovery or mitigation plan. Typically, provisions that define the degree to which the contractor's actual construction approach can deviate from the plan as depicted in the schedule are included in the contract. This can be accomplished by specifying the number of days the contractor's prediction of completion can fall behind the contractual completion date. Often, these provisions give the owner the right to demand a revised schedule showing timely completion. These provisions also often give the owner the right to withhold all or part of the progress payments that would be otherwise due until an acceptable revised schedule showing a recovery plan is submitted. If properly submitted time extension requests are not resolved before the owner demands a recovery plan, the contractor may be entitled to the costs to accelerate to achieve the recovery.



Operational schedules – Short-interval schedule

Short-Interval Schedule – If a short-interval schedule (SIS) is to be required, this requirement should be reflected in the contract. A SIS is generally a 2- to 3-week detailed look ahead at the contractor's work plan. Generally, it is in greater detail than a construction schedule but correlates with construction schedule durations for performance. See *Cost Management Guidelines* for more details.

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Operational schedules – As-built schedule

The as-built schedule documents completed actions, records what actions were accomplished and when, records warranty and startup actions, tallies costs if the schedule is cost-loaded, and provides one source of historical information for any unresolved disputes and claims. It is important that the actual dates and activities are validated when finalizing the as-built schedule. Inaccurate data in the project as-built schedule reduces its value and can hinder the resolution of remaining disputes.

The final update of the construction schedule should become the as-built schedule for the project. Though it is unlikely that this schedule will eliminate the need for a more detailed daily as-built should there be a claim on the project, it can serve as the basis for such a schedule. If used this way, the final update can be augmented by data from the daily reports, meeting minutes, photographs, correspondence, and other detailed project records that map the daily activities during the project.

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Organizing schedule data

- ❑ By **sorting activities** on different bases, different forms of useful information become available to project management personnel.
- ❑ **Various types of sorts:**
 - ❖ Activity number sort
 - ❖ Early-start sort
 - ❖ Late-start sort
 - ❖ Late-finish sort
 - ❖ Total float sort
 - ❖ Project responsibility
 - ❖ Combined sort

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Organizing schedule data – Total float sort

Activity (Bold type denotes critical activities)	Activity Number	Duration (Working Days)	Expected Start Date A.M.	Total Float
Prepare & approve S/D, abutment & deck rebar	10	10	June-14	0
Fabricate & deliver abutment & deck rebar	60	15	June-28	0
Forms & rebar, abutment #1	180	4	July-20	0
Pour abutment #1	200	2	July-26	0
Strip & cure, abutment #1	220	3	July-28	0
Forms & rebar, abutment #2	240	4	August-2	0
Pour abutment #2	250	2	August-6	0
Strip & cure, abutment #2	290	3	August-10	0
Set girders	320	2	August-13	0
Deck forms & rebar	330	4	August-17	0
Pour & cure deck	340	3	August-23	0
Strip deck	350	3	August-26	0
Painting	370	5	August-31	0
Cleanup	390	3	September-8	0
Final inspection	400	1	September-13	0
Guardrails	360	3	August-31	2
Order & deliver piles	30	15	June-14	3
Drive piles, abutment #1	110	3	July-6	3
Forms & rebar, footing #1	130	2	July-9	3
Drive piles, abutment #2	140	3	July-14	3
Pour footing #1	150	1	July-13	3
Demobilize pile driving rig	160	1	July-14	3
Strip footing #1	170	1	July-14	3
Backfill abutment #2	310	3	August-13	3

Organizing schedule data – Total float sort

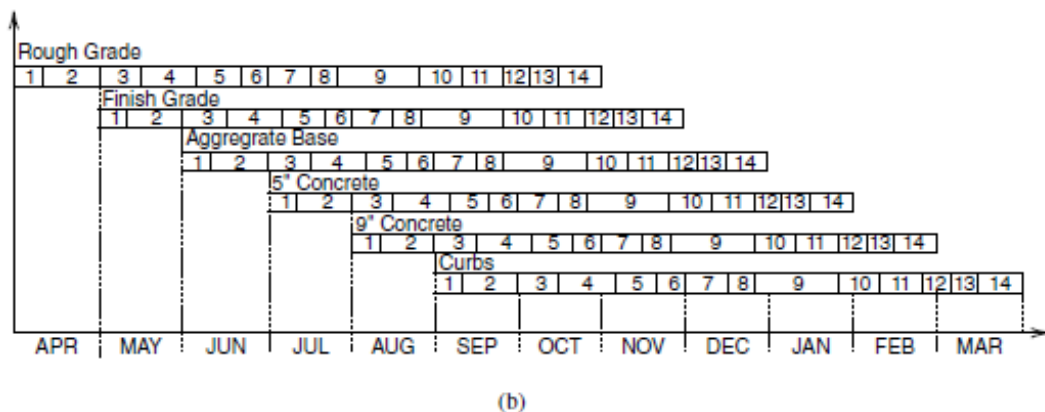
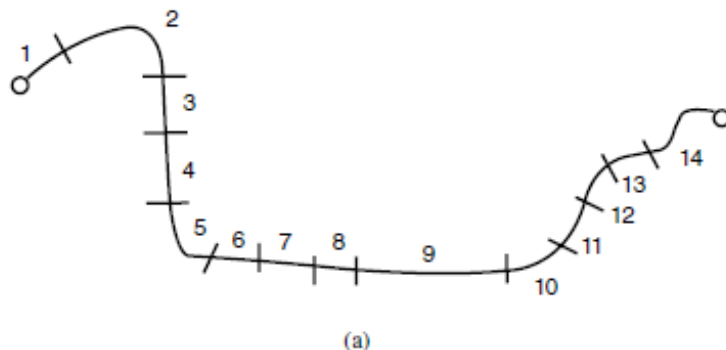
ID	Task Name	Start	Finish	Late Start	Late Finish	Free Slack	Total Slack
1	Start	Mon 12/16/13	Mon 12/16/13	Mon 12/16/13	Mon 12/16/13	0 days	0 days
4	Site Work	Mon 12/16/13	Tue 3/18/14	Mon 12/16/13	Tue 3/18/14	0 days	0 days
10	Drilled Piers	Wed 1/15/14	Tue 1/28/14	Wed 1/15/14	Tue 1/28/14	0 days	0 days
11	Grade Beams & Slabs	Wed 1/29/14	Tue 3/11/14	Wed 1/29/14	Tue 3/11/14	0 days	0 days
12	Structural Erection	Wed 3/12/14	Tue 4/1/14	Wed 3/12/14	Tue 4/1/14	0 days	0 days
15	Framing	Wed 4/2/14	Tue 5/13/14	Wed 4/2/14	Tue 5/13/14	0 days	0 days
18	Insulation	Wed 5/14/14	Wed 6/25/14	Wed 5/14/14	Wed 6/25/14	0 days	0 days
19	Gypsum Drywall	Thu 6/26/14	Thu 8/7/14	Thu 6/26/14	Thu 8/7/14	0 days	0 days
27	Paint	Fri 8/8/14	Fri 9/26/14	Fri 8/8/14	Fri 9/26/14	0 days	0 days
28	Millwork	Mon 9/29/14	Fri 10/24/14	Mon 9/29/14	Fri 10/24/14	0 days	0 days
40	Electrical, RI Partitions	Wed 5/14/14	Wed 6/25/14	Wed 5/14/14	Wed 6/25/14	0 days	0 days
44	Closeout	Mon 10/27/14	Fri 10/31/14	Mon 10/27/14	Fri 10/31/14	0 days	0 days
33	HVAC Finish	Mon 9/29/14	Fri 10/17/14	Mon 10/6/14	Fri 10/24/14	5 days	5 days
35	Plumbing in Partitions	Wed 5/14/14	Wed 6/18/14	Wed 5/21/14	Wed 6/25/14	5 days	5 days
36	Plumbing Fixtures	Mon 9/29/14	Fri 10/17/14	Mon 10/6/14	Fri 10/24/14	5 days	5 days
38	Fire Protection, Finish	Mon 9/29/14	Fri 10/17/14	Mon 10/6/14	Fri 10/24/14	5 days	5 days
43	Fire Alarm, Finish	Mon 10/6/14	Fri 10/17/14	Mon 10/13/14	Fri 10/24/14	5 days	5 days
7	Site Paving, Finish	Fri 8/1/14	Thu 8/28/14	Fri 8/15/14	Fri 9/12/14	0 days	10 days
8	Irrigation	Fri 8/29/14	Fri 9/19/14	Mon 9/15/14	Fri 10/3/14	0 days	10 days
9	Landscape	Mon 9/22/14	Fri 10/10/14	Mon 10/6/14	Fri 10/24/14	10 days	10 days
14	Roofing	Wed 4/2/14	Tue 4/29/14	Wed 4/16/14	Tue 5/13/14	0 days	10 days
16	Dampproof	Wed 5/14/14	Wed 6/18/14	Thu 5/29/14	Wed 7/2/14	0 days	10 days
17	Masonry	Thu 6/19/14	Thu 7/31/14	Thu 7/3/14	Thu 8/14/14	0 days	10 days
29	Signage	Mon 9/29/14	Fri 10/17/14	Mon 10/13/14	Fri 10/31/14	0 days	10 days
20	Aluminum Frames	Wed 5/14/14	Wed 6/25/14	Thu 6/5/14	Thu 7/17/14	0 days	15 days
21	Wood Doors	Thu 6/26/14	Thu 7/17/14	Fri 7/18/14	Thu 8/7/14	15 days	15 days
24	Ceilings	Fri 8/8/14	Fri 9/5/14	Mon 9/8/14	Fri 10/3/14	0 days	20 days
25	Ceramic Tile	Fri 8/8/14	Fri 9/5/14	Mon 9/8/14	Fri 10/3/14	0 days	20 days
26	Flooring	Mon 9/8/14	Fri 9/26/14	Mon 10/6/14	Fri 10/24/14	20 days	20 days

pour
BUTE

Schedule presentation formats

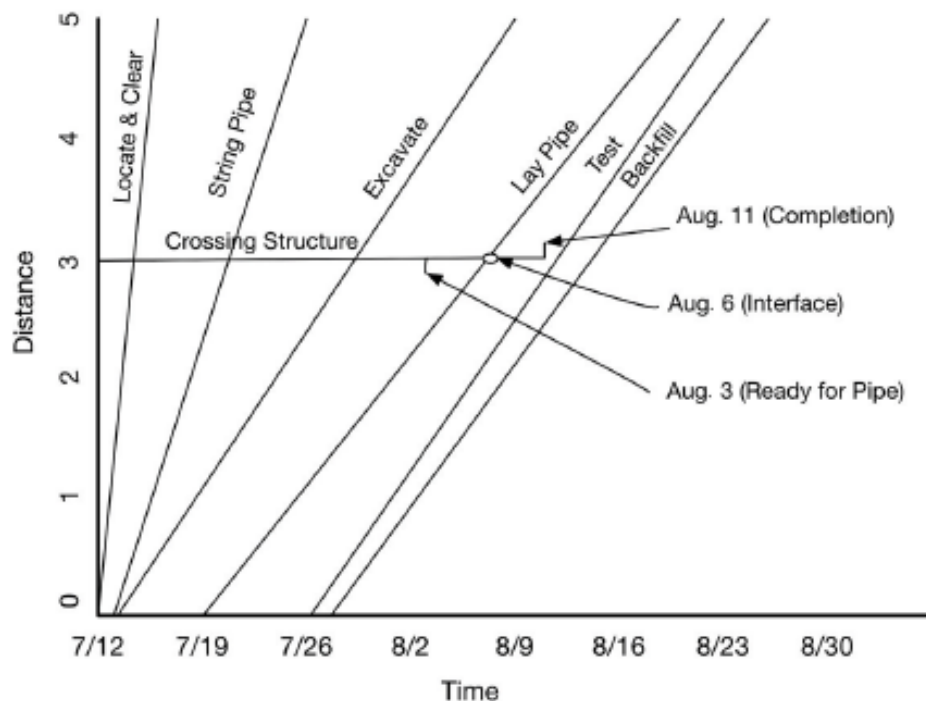
- ❑ Once a **schedule** has been prepared, it may be presented in a **number of different visual formats** depending on its **purpose and audience**.
- ❑ Presenting a schedule in the **proper visual format** highlights the information the project manager is trying to convey and **makes the schedule a better communication tool**.
- ❑ This section explores several industry standard presentation formats and the information and audiences they target.
 - ❖ **Precedence networks**
 - ❖ **Gantt charts**
 - ❖ Time-scaled logic
 - ❖ Line-of-balance schedules

Schedule presentation formats – Line of balance



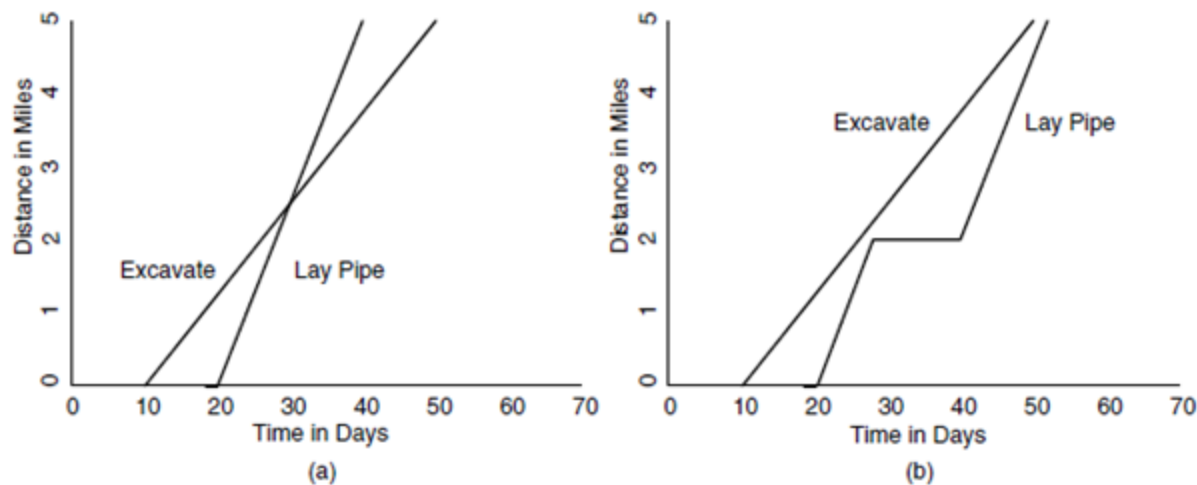
Road project divided into 14 sections

Schedule presentation formats – Line of balance



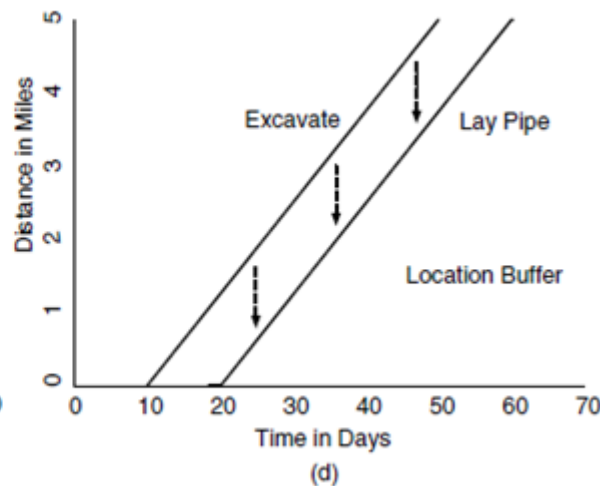
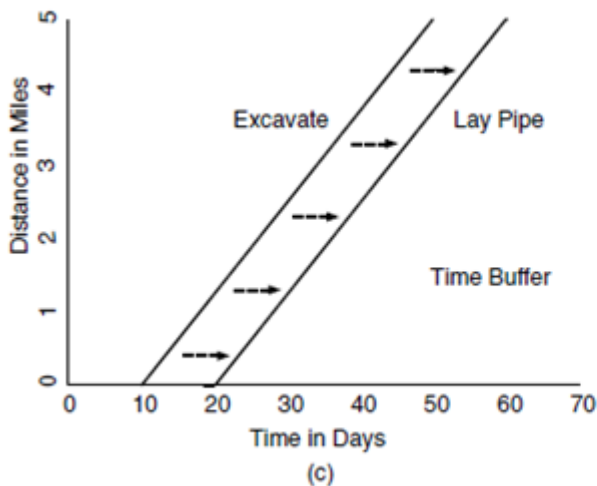
Schedule presentation formats – Line of balance

❑ Resolving line-of-balance conflicting activities



Schedule presentation formats – Line of balance

☐ Time and location buffer



Legal schedules

- ☐ This section considers some of the **legal aspects** of a **project schedule**.
- ☐ The discussion here is general and should not be considered a substitute for legal advice.
- ☐ The topics that follow are important considerations in planning, scheduling, and submitting schedules for review and approval.

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Legal schedules

❑ The schedule is a double-edged sword with the **potential to damage** the position of either party in a dispute.

- ❖ Right to finish early
- ❖ Owner approval of the schedule
- ❖ Cost and Resource-loaded schedules
- ❖ Legal need for a schedule
- ❖ Schedule narrative

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Legal schedules – Early completion

Early Completion Schedules – The contract should address the acceptability of early completion schedules: baseline schedules (subsequent schedule updates can show early completion with no specific contractual acceptance risks) that show scheduled project completion dates earlier than the contract completion dates. The options available to the CM include: recommending that early completion schedules be rejected because they show early completion; recommending that such schedules be accepted; recommending that such schedules be accepted but that the time between the scheduled early completion date and the contract date be defined as float; or recommending that the contract stipulate that the contract completion date be revised (by change order) to match the scheduled early completion date. This last alternative would mean that liquidated damage assessments, if any, would be made from the revised earlier completion date, not the original contract date.

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Legal schedules – Early completion

The CM must understand the ramifications of early completion schedules and determine the owner's ability to receive a project on an early completion. This could require additional funding to cover the costs of security, heating and cooling, and utilities, among others, as well as early start of equipment warranty periods when the facility may not be operating at full capacity and thus not place the equipment under full load during the warranty.

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Legal schedules – Schedule acceptance

Schedule Acceptance – The owner's right to review the schedule and the procedures and protocols to be followed related to the review and acceptance process, as well as the contractor's responsibility to conform to the owner's review comments, must be defined in the contract documents.

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Legal schedules – Cost and Resource loading

Cost and Resource Loading – If contractor payments are based on schedule progress, the contract must include cost-loaded schedules and payment provisions. The value of resource loading is enhanced when schedules are combined and resources are managed at the enterprise level. Knowing which resources a contractor intends to mobilize for the project in order to achieve the scheduled productivity significantly enhances the CM's ability to monitor the progress of work and potentially foresee and analyze the sources of delays. Cranes are a typical example of a limiting resource. It is difficult to resolve concurrent delay because it is unlikely that two delays will occur at the exact same time and for the exact same duration

Legal schedules – Narrative reports

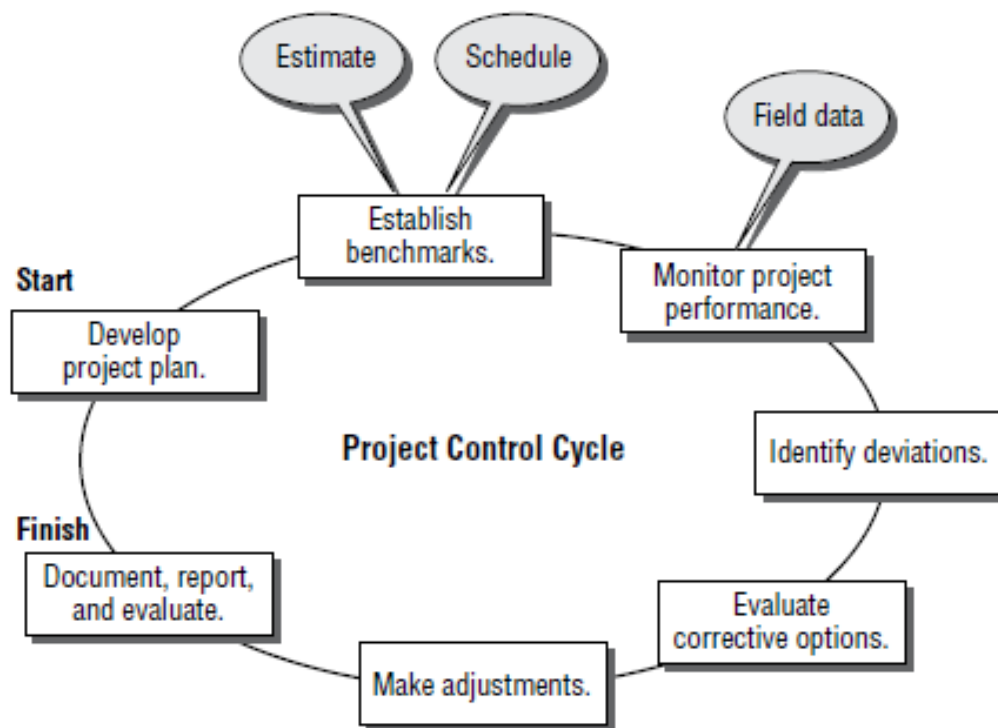
Narrative Reports – A narrative report should be submitted with each schedule: preliminary, baseline and update. A narrative report assists the project team in thinking through project progress during the previous update period, the impact of major events during the period, the causes of delays, if any, and actions that may be necessary in the future as a result of the project events. The narrative also helps the CM understand the contractor's means and methods so as to ensure that the schedule logic and sequencing reflect the contractor's intent.

The narrative should require: executive summary, areas of progress, delays or potential delays, time extension requests, logic and duration changes, resource consumption or usage, recovery plans, and an overall assessment of schedule achievement. The well-written narrative provides crucial insight into the contractor's intentions, enhances the communication value of the schedule, and minimizes scheduling issues.

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PROJECT COORDINATION

Project control cycle



The feedback loop

- ☐ At the **heart** of every project control system are **information and a good reporting** process.
- ☐ Successful construction management and project control depend on **sound information**, which comes from **actual project performance data**.
- ☐ This data **originates** in the field and is reported on a daily, weekly, and monthly basis.

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The feedback loop

❑ The following are some of the sources of information used to **track job performance** and **feedback** into the project control system:

- ◆◆ Daily field reports
- ◆◆ Time cards
- ◆◆ Subcontractor billing statements
- ◆◆ Delivery tickets
- ◆◆ Material invoices
- ◆◆ Equipment time tickets
- ◆◆ Job logs

Schedule types during construction

- ❑ Schedules can also be prepared as **different presentations**, depending upon the **anticipated use**.

- ❖ **Contract schedules, also known as formal schedules:**

These schedules will be provided to the **client** at the beginning and throughout the project delivery as required by the contract special conditions.

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Schedule types during construction

- ❑ Schedules can also be prepared as **different presentations**, depending upon the **anticipated use**.

- ❖ **Initial or Preliminary Schedule**

A **schedule detailing** the project plan for the **first 60 to 120 days of work** may be required to cover the earliest work activities on the project while the **full baseline** schedule is being developed.

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Schedule types during construction

- ❑ Schedules can also be prepared as **different presentations**, depending upon the **anticipated use**.

- ❖ **Summary schedules:**

These schedules are often used for presentations, proposals, or management reporting.

They are an **abbreviated version** of a detailed construction schedule, which may include **20– 30 major activities**.

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Schedule types during construction

- ❑ Schedules can also be prepared as **different presentations**, depending upon the **anticipated use**.

- ❖ **Detailed schedules:**

These schedules are posted on the walls of meeting rooms or in the jobsite trailer.

They are **marked up** with comments and progress.

These schedules may also serve as **submittals** for the contract schedule requirements.

The **complete detailed schedule** would be 80–100 items longer.

Schedule types during construction

- ❑ Schedules can also be prepared as **different presentations**, depending upon the **anticipated use**.

- ❖ Short- interval “look ahead” schedules:

- ✓ These schedules focus on **short-term field activities**.
- ✓ These schedules can be in two- , three- , or four- week increments, depending upon the job and level of activity.
- ✓ Some contractors **simply print** the activities for the next three weeks from the electronic **master schedule** without any additional detail or input from the **superintendent**.
- ✓ The schedule format is **not as important** as its author and content.
- ✓ This **superintendent** prepared the schedule by **using Excel**.

Schedule types during construction

- ❑ Schedules can also be prepared as **different presentations**, depending upon the **anticipated use**.

- ❖ **Short- interval “look ahead” schedules:**

- ✓ They should be developed by each superintendent or foreman and each subcontractor **each week**.
- ✓ They may be **drafted** by hand in **bar chart form**, on an Excel spreadsheet, or with scheduling software.
- ✓ The **form or system** does not matter.
- ✓ What is important is that they are **produced by the people** who are doing the work and that they are communicated and distributed to **all involved**.
- ✓ In this way, they are construction management tools.

Schedule types during construction

- ❑ Schedules can also be prepared as **different presentations**, depending upon the **anticipated use**.

- ❖ Mini-schedules, area schedules, and system schedules:

- ✓ These schedules are intended to allow additional detail for **certain portions of the work**

that **could not be adequately** represented in the project detailed schedule and have longer durations than the **short interval schedule**.

Schedule types during construction

- ❑ Schedules can also be prepared as **different presentations**, depending upon the **anticipated use**.

❖ Pull schedules:

- ✓ These schedules are the product of **pull-planning exercises** that are one of the major lean construction tools being adapted from **production industries**.



Schedule types

- ❑ Schedules can also be prepared as **different presentations**, depending upon the **anticipated use**.

- ❖ **Other schedules:**

- ✓ There may be many other **specialized schedules** on the project that include submittal, buyout, delivery, start-up, and close-out schedules.

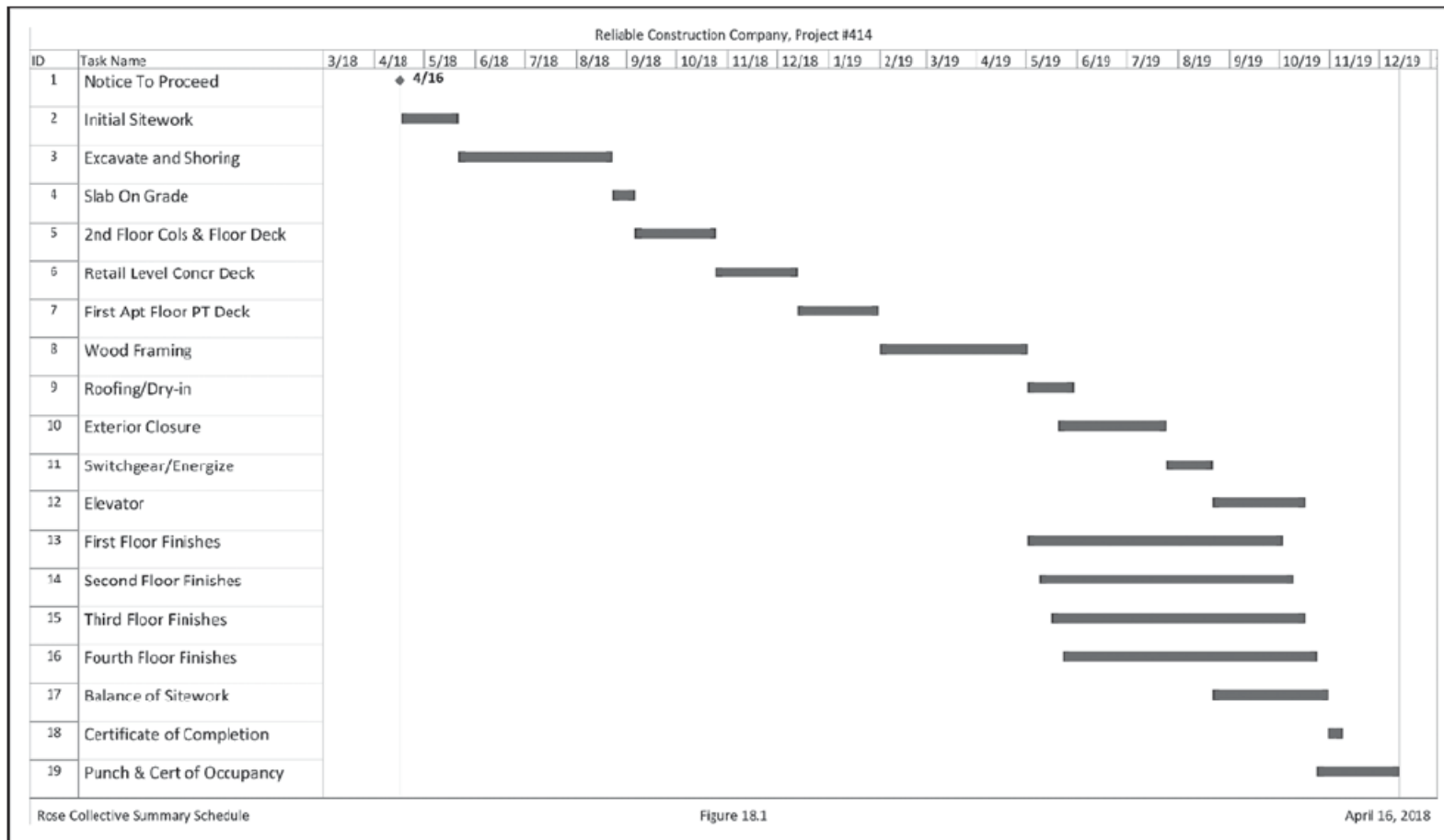
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Detailed schedule

❑ Initial detailed schedule

Detailed Schedule							
Project <u>Highway Bridge</u> Project No. <u>200808-05</u>				Prepared by <u>G.A.S.</u> Date <u>June 14</u>			
Activity	Activity Number	Scheduled Duration (Working Days)	Scheduled Start Date	Scheduled Completion Date	Free Float (Working Days)	Actual Start Date	Actual Completion Date
Move in	40	3	25-Jun	29-Jun	0		
Prefabricate abutment forms	80	3	30-Jun	2-Jul	10		
Excavate abutment #1	90	3	30-Jun	2-Jul	0		
Mobilize pile-driving rig	100	2	30-Jun	1-Jul	1		
Excavate abutment #2	120	2	6-Jul	7-Jul	1		
Drive piles, abutment #1	110	3	6-Jul	8-Jul	0		
Forms & rebar, footing #1	130	2	9-Jul	12-Jul	0		
Drive piles, abutment #2	140	3	9-Jul	13-Jul	0		
Pour footing #1	150	1	13-Jul	13-Jul	0		
Demobilize pile-driving rig	160	1	13-Jul	13-Jul	3		
Strip footing #1	170	1	14-Jul	14-Jul	0		
Forms & rebar, footing #2	190	2	15-Jul	16-Jul	0		
Pour footing #2	210	1	19-Jul	19-Jul	0		
Strip footing #2	230	1	20-Jul	20-Jul	8		
Forms & rebar, abutment #1	240	4	20-Jul	23-Jul	0		
Critical activities in bold							

Summary schedule



Look-ahead schedule

☐ Seven-day look-ahead schedule

short-interval schedules

Also called look-ahead schedules, they are typically prepared by superintendents and focus on relatively short periods of time, such as two to six weeks. These schedules are usually provided to trade contractors and focus on specific areas of work in greater detail than is provided in the overall project schedule.

Look-ahead schedule for 7/30 to 8/9 (Forms & Rebar, Abutment #2)							
Mike R. Carpenter Foreman							
Task	7/30 Friday	8/2 Monday	8/3 Tuesday	8/4 Wednesday	8/5 Thursday	8/6 Friday	8/9 Monday
Clean, repair, and oil forms 2 laborers	4 mh						
Place inside forms 2 carpenters 4 laborers 1 crane operator		56 mh					
Plumb & brace inside forms 1 carpenter 2 laborers			12 mh				
Coordinate with rebar sub to set abutment rebar							
Place outside forms 2 carpenters 4 laborers 1 crane operator			56 mh				
Plumb & brace outside forms 1 carpenter 2 laborers				12 mh			
Crane usage Shared with rebar sub as required							

Look-ahead schedule

Worksheet 4.1 Short interval schedule

SHORT INTERVAL SCHEDULE																									
NORTHWEST CONSTRUCTION COMPANY																									
PROJECT: NanoEngineering Building																									
SUPERINTENDENT: Jim Bates																									
March 2015													April 2015												
NO.	ACTIVITY DESCRIPTION:	S	S	23	24	25	26	27	S	S	30	31	1	2	3	S	S	6	7	8	9	10	S	S	COMMENTS
1	Notice to Proceed					X																			Original in Office
2	Deliver Office Trailers						X																		
3	Install Silt Fence							X			X	X													
4	Survey Corners							X																	
5	Locate Utilities										X														
6	Install Temp Power													X	X										
7	Deliver Sanikan							X																	
8	Clear and Grub Site																				X	X			Finish Monday
9	Precon Meeting with City										X														
10	Mobilize Demolition Sub											X													
11	Demo Existing Structure												X	X	X			X	X	X	X				
12	Geo Approve Import Sample													X	X			X	X	X	X	X			Expedite!
13	Utility Relocates																								Post Clear & Grub

Progress measurement

- ☐ To make **periodic measurements** of progress in the **field**, network activities serve as **exceptionally convenient packages** of work.
- ☐ The **advancement of an activity** in **progress** can be expressed in different ways.
- ☐ **Three commonly used** methods are:
 1. Estimated number of working days remaining to complete the activity.
 2. Estimated percentage completion of the activity in terms of time.
 3. Quantities of work units put into place.

Progress measurement

- ☐ **How a contractor** chooses to express **activity completion** depends on the type of work involved and whether these same data are also **used to check field costs**.
- ☐ However, the number of working days remaining to finish an activity is **fundamental** to the workings of project time management.

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Progress measurement

- ❑ **Progress data** in the other forms are readily converted into **days to complete** by using these relationships:

$$\text{Working days to complete} = d(1 - P / 100)$$

$$\text{Working days to complete} = d(1 - W / T)$$

where

d = total activity duration in working days

P = estimated percentage of completion

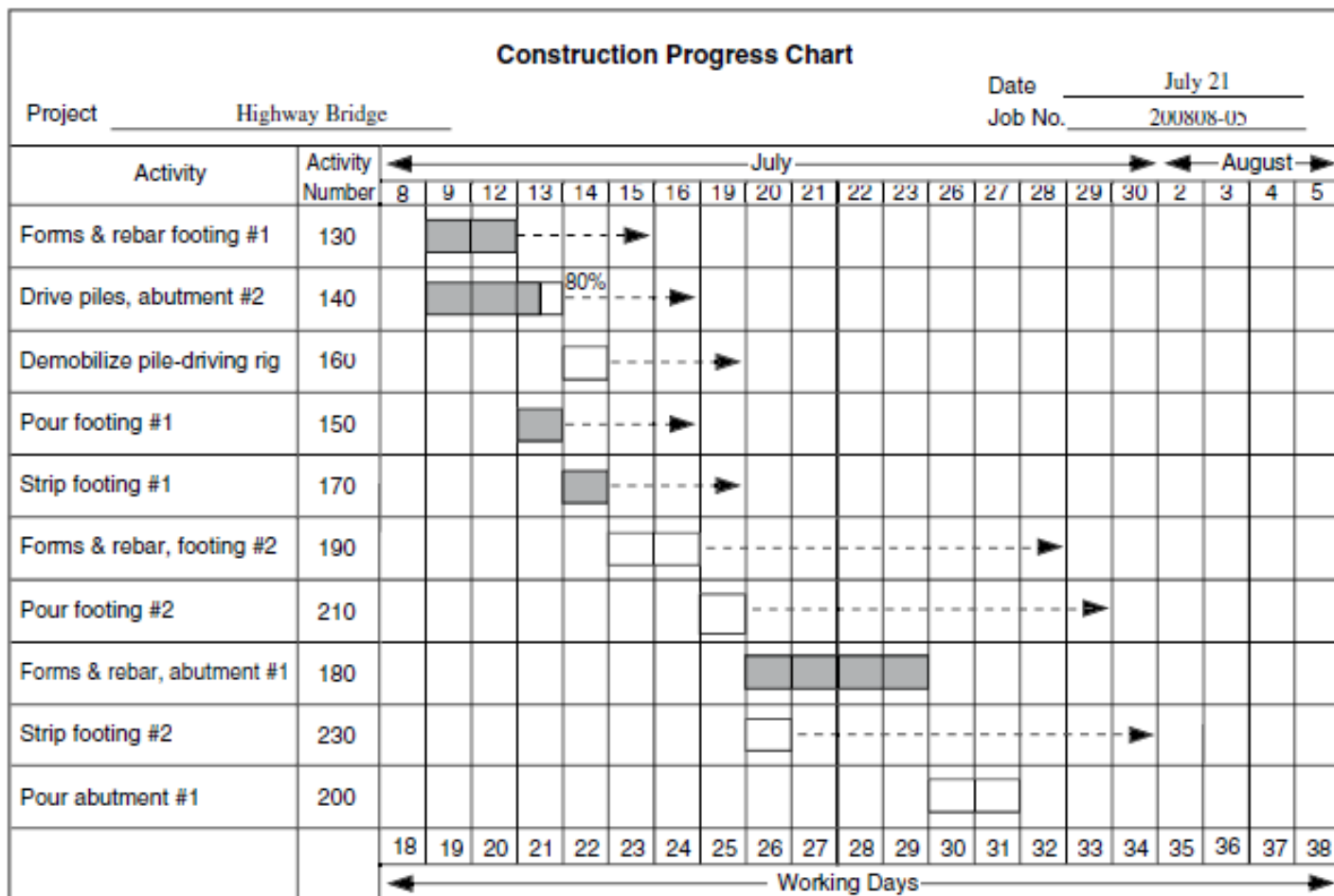
W = number of work units put into place

T = total number of work units associated with the activity

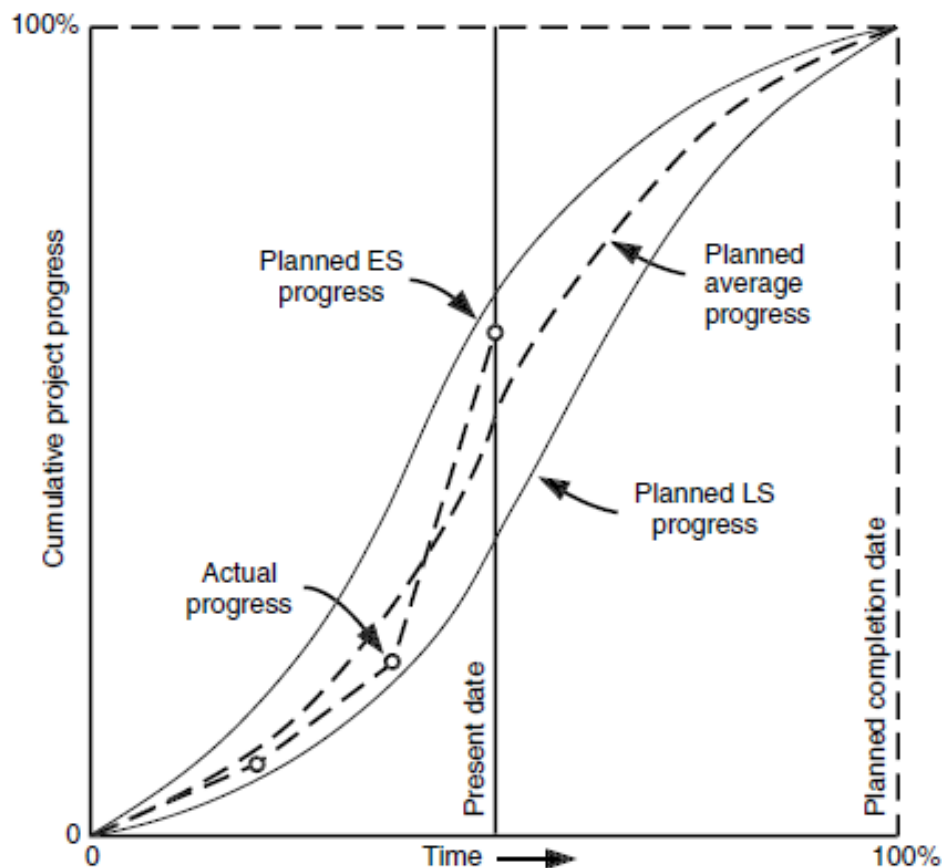
Progress reporting – Weekly progress reports

Weekly Progress Report					
Project	Highway Bridge		Week ending	Wed., 21-Jul (Working day 27)	
Job No.	200808-05		Prepared by	GAS	
Activity	Activity Number	Date Started	Date Completed	Percent Complete	Working Days to Complete
Fabricate & deliver abutment rebar	60	–	15-Jul	100	0
Fabricate & deliver deck rebar	65	–	–	–	13
Drive piles, abutment #2	140	12-Jul	–	80	2
Strip footing #1	170	15-Jul	15-Jul	100	0
Forms & rebar, abutment #1	180	16-Jul	21-Jul	100	0
Fabricate & deliver girders	260	–	–	–	10

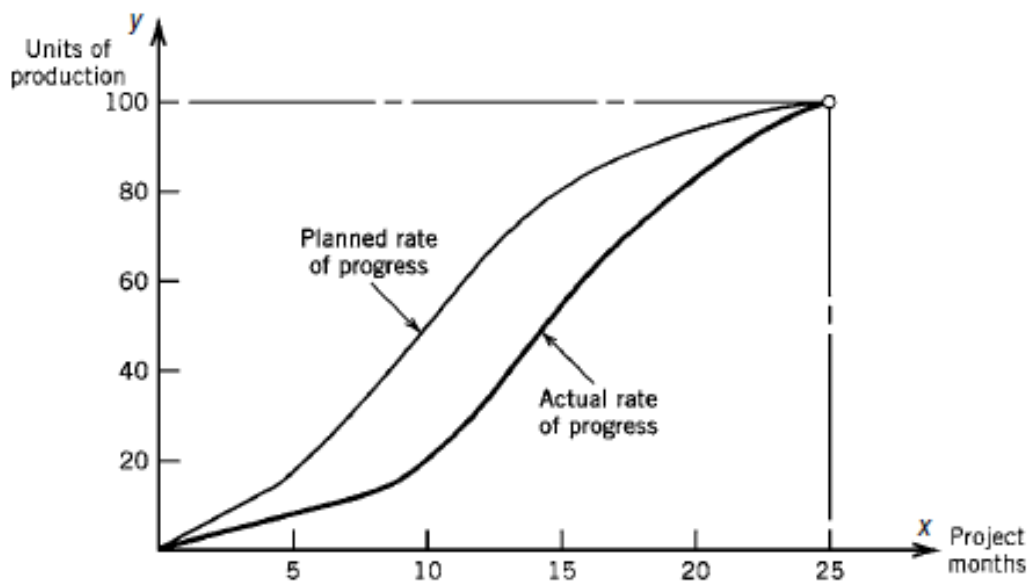
Progress reporting – Weekly progress chart



Progress reporting – Progress curves



Progress reporting – Production curves



Progress analysis

- ☐ The **analysis of job progress** is concerned primarily with determining the effect of this latest information on the project completion date and any intermediate time goals that have been established.
- ☐ **Considerable attention** has been given to the fact that the length of the critical path determines the time required to reach a given network event.
- ☐ Practically, then, the analysis of progress data is concerned essentially with determining, as closely as possible, the present length and location of the **applicable critical path**.

Progress analysis – Current critical path

- ❑ When a **progress report** is received from the field, the **status** of the currently identified critical activities is probably the **first item noted**.
 - ❖ This is a **quick and simple** check.
 1. If these **critical activities** have been **accomplished** by their scheduled finish times, there is no problem with the project time goal insofar as the current critical path is concerned.
 2. If a critical activity has been **started late**, a **setback** in project completion is likely, **unless the delay** can be somehow made up by the time the **activity is completed**.
 3. If a critical activity has been **finished late**, the **completion date** is **delayed** commensurately.

Progress analysis – New critical path

- ❑ The next step in the analysis is to **check the possibility** that a new critical path has been formed.
- ❑ This can be done by subjecting the **noncritical activities** to either of two different checks.
 - ❖ One of these checks involves using either a late-start activity sort or a late-finish activity sort.
 1. A late-start sort is an activity listing ordered according to the **latest allowable starting times (LS)**.
 2. A late-finish sort is a similar listing in terms of **the latest allowable finish dates (LF)**.

Progress analysis – New critical path

- ☐ The next step in the analysis is to **check the possibility** that a new critical path has been formed.
- ☐ This can be done by subjecting the **noncritical activities** to either of two different checks.
- ☐ One of these checks involves using either a late-start activity sort or a late-finish activity sort.
 1. If an activity has **missed** its **LS date**,
the project is behind, according to the **current action plan**.
 2. If an activity did **not finish** by its LF date,
there is now a new critical path, and
the **job is delayed** by the amount that this activity completion
trailed the **LF time**.

Schedule analysis to determine project delays

- ❑ It was stated previously that the project schedule is **updated weekly or monthly**.
 1. When a delay occurs on a project, the **delay is reflected** in the updated schedule by
 1. Adding more time to the **original activities** or
 2. Through the addition of new activities.
 - i. When the **contractor is responsible** for the delay, the **lost time** must be made up at the contractor's expense.
 - ii. When the **owner causes the delay**, the contractor must request additional contract time.

Schedule analysis to determine project delays

- ☐ It is the contractor's responsibility to **notify the owner**, in writing, of the delay.
- ☐ The request for additional time must be supported with **evidence satisfactory** to the **owner**.
- ☐ Although simple in concept, this **process** can become very complicated and burdensome.

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Schedule analysis to determine project delays

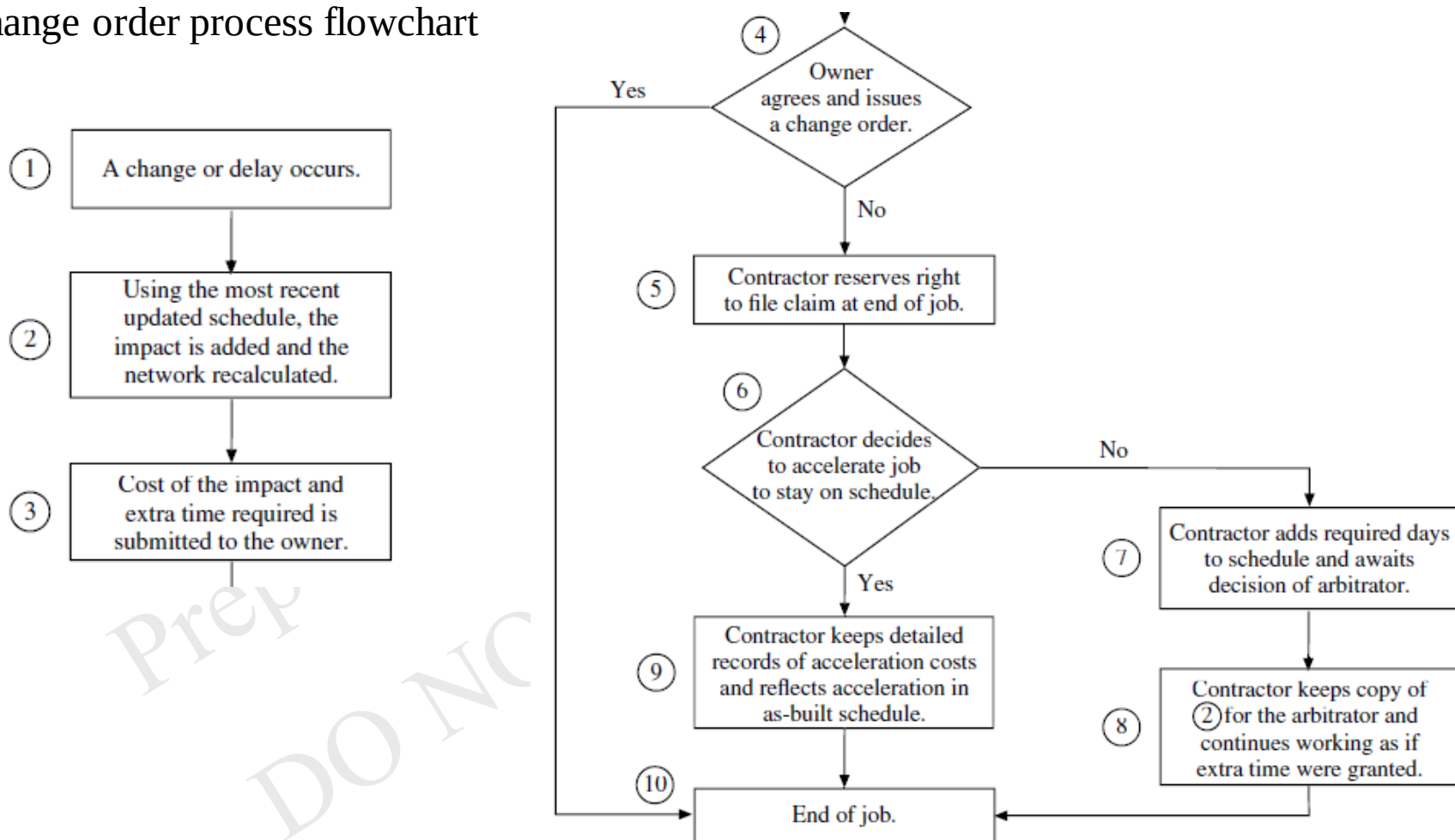
- ☐ Should the **owner** authorize additional project time based on the evidence,
 1. A **contract change order** is issued and
 2. The matter of the **delay is concluded**.

- ☐ If the **owner rejects** the delay and **refuses to issue** a change order, the **contractor** must give notice of a formal claim.

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Schedule analysis to determine project delays

❑ Change order process flowchart



Schedule analysis to determine project delays

❑ **Regardless** of whether the owner grants extra time for a delay or not,

1. The **updated schedule** showing the effect of the delay, and
2. Prepared contemporaneously with the delay,

is the **best method** for **proving a delay claim** that will prevail.

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Schedule analysis to determine project delays

- ☐ Whenever possible, the **effects of a change** should be identified, quantified, and resolved concurrently by the people currently involved with the project.
- ☐ When **delay decisions** are deferred,
 1. Memories fade,
 2. Project personnel change, and
 3. Dispute becomes personalized.
- ☐ If **resolution is delayed**, eventually
 1. The dispute is adjudicated,
 2. Attorneys are involved,
 3. The cost of the claim increases dramatically, and
 4. A fair and equitable resolution is more remote.

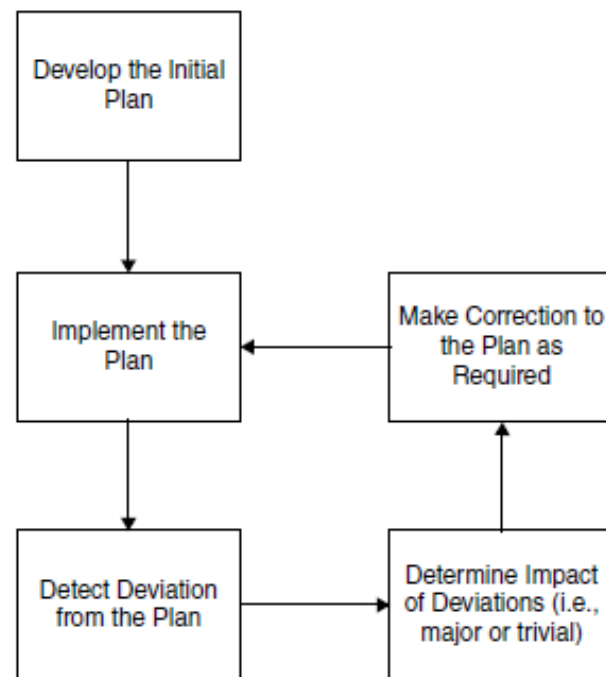
Schedule analysis to determine project delays

- ❑ When **no possibility** of a timely analysis exists,
the **contractor must**, after the fact, utilize an **analytical scheduling technique** to
re-create the project on paper in order to prove entitlement.

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Corrective action

- ❑ After each **progress report** has been **analyzed**, a decision must be made concerning what corrective action, if any, is required.
- ❑ **Small delays**, actual or potential, usually will **not require any particular corrective action**, provided that the usual contingency allowance has been included in the project duration.



Network updating

☐ Network update information

Item	Network Update Information as of July 21 (working day 27)
1	Add activity 65, "Fabricate & deliver deck rebar."
2	Anticipated delivery date of deck rebar is August 9 (working day 40). Activity 65 requires $40 - 27 = 13$ working days to complete.
3	The estimated time to complete activity 140 is 2 working days. Driving rate is very slow due to boulders and tightly packed gravel.
4	Anticipated delivery date for the girders is August 4 (working day 37). Activity 260 requires $37 - 27 = 10$ working days to complete.
5	The estimated time to accomplish activity 330, "Deck forms & rebar," has been revised upward from 4 to 6 working days.
6	A 25-ton crane was brought in and used to place the forms and rebar in activity 180. This removed the dependency between activity 160 and 180. A dependency was established between activity 160 and 240.

Software

NOTE

Several popular construction scheduling software programs are available. They include Oracle Primavera (P6), Elecosoft Asta Powerproject, and Microsoft Project. Sometimes the contract will actually require the contractor to use a particular software program because it corresponds to the system that the owner already uses internally. When this happens, the contractor is obliged to buy, learn, and use the new software, or propose an alternative and then train the owner.

Software

7. Don't Focus Too Much On Project Controls Software

While the software is an incredibly helpful tool to use in project controls, Chris cautions against focusing too intently on software:

"People often tend to focus on software as if that's going to solve the problem. The software is not that important of an issue...the real talent; the real skill that you're developing is not your software skills."



At the end of the day, your main goal should be to improve your own skills and abilities, not to look for new software to understand how to do your job. Software is important, but it's not everything. If you do not understand how to develop a reasonable schedule or build an accurate estimate, the software will simply make you look bad.

Focus first on self-improvement and then on the ways that software can help – not the other way around. You need to understand how to do your discipline, provide the best services and do so efficiently. Once you have this down, you can learn a bit more about software.

<https://dralavipour.com/blog/view/project-controls-expert>

**CM ROADMAP
RELATED TO THIS SECTION**

CM Roadmap – Hard skills

مهارت‌های سخت (Hard Skills) - سطح کارشناسی و اجرایی					
سطح ۵	سطح ۴	سطح ۳	سطح ۲	سطح ۱	دپارتمان‌ها
	استاندارد مدیریت ساخت CMAA	متدولوژی Prince2	راهنمای PMBOK	مدیریت پروژه‌های صنعت ساخت	مدیریت پروژه
	تامین مالی پروژه			مدیریت مالی و هزینه پروژه ارزیابی اقتصادی پروژه	مدیریت مالی و هزینه
				برنامه‌ریزی و کنترل پروژه نرم‌افزار MSP نرم‌افزار P6	مدیریت برنامه‌ریزی و زمان‌بندی
		مدیریت کیفیت پروژه			مدیریت کیفیت
اجرای پروژه به روش CM			مدیریت ادعاء و اختلافات	آنالیز تاخیرات پروژه	مدیریت قرارداد
		مدیریت ایمنی پروژه			مدیریت ایمنی
مدیریت طرح		مدیریت چابک Agile	مدیریت پروژه به روش Lean دفتر مدیریت پروژه (PMO)		مدیریت طرح و برنامه
		مدیریت پایداری پروژه			مدیریت پایداری
			مدیریت ریسک پروژه		مدیریت ریسک
			نرم‌افزار Power BI	مدیریت اسناد و مدارک پروژه	مدیریت اطلاعات
	مدیریت BIM در پروژه		نرم‌افزارهای BIM		مدیریت مدل‌سازی اطلاعات ساختمان (BIM)

Relevant comprehensive courses



آموزش نرم‌افزار P6 Primavera در مدیریت پروژه

<https://dralavipour.com/general-course/Primavera3>



آموزش نرم‌افزار Microsoft Project در مدیریت پروژه

<https://dralavipour.com/general-course/msp3>



فرآیند یکپارچه برنامه‌ریزی، زمان‌بندی، ارزیابی و کنترل پروژه

<https://dralavipour.com/general-course/scheduling2>

Relevant comprehensive courses



مدیریت پروژه چابک (Agile) با نگاهی به
صنعت ساخت (مفاهیم، تفکراتها و ابزارها)

[https://dralavipour.com
/general-course/agile](https://dralavipour.com/general-course/agile)



پیاده سازی و توسعه دفتر مدیریت پروژه
(PMO) در راستای دفتر مدیریت طرح

[https://dralavipour.com
/general-course/pmo2](https://dralavipour.com/general-course/pmo2)



اجرا و مدیریت پروژه به روش اصول ناب
(Lean Project Management)

[https://dralavipour.com
/general-course/lean1](https://dralavipour.com/general-course/lean1)

Relevant comprehensive courses

Construction Program Management
Next years...

<https://dralavipour.com/general-course/construction-program-management>

CM Roadmap – Hard skills

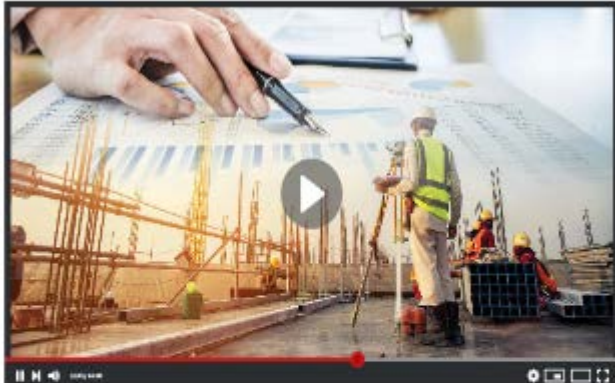
مهارت‌های سخت (Hard Skills) - سطح ارشد استراتژی					
سطح ۵	سطح ۴	سطح ۳	سطح ۲	سطح ۱	دپارتمان‌ها
		منشور اخلاق در مدیریت پروژه			مدیریت پروژه
			استراتژی مدیریت هزینه و مهندسی ارزش		مدیریت مالی و هزینه
			استراتژی مدیریت برنامه‌ریزی و زمان‌بندی		مدیریت برنامه‌ریزی و زمان‌بندی
	استراتژی مدیریت کیفیت				مدیریت کیفیت
		استراتژی مدیریت قرارداد		اصول مدیریت ساخت	مدیریت قرارداد
	استراتژی مدیریت ایمنی				مدیریت ایمنی
استراتژی مدیریت طرح و برنامه					مدیریت طرح و برنامه
	استراتژی مدیریت پایداری				مدیریت پایداری
		استراتژی مدیریت ریسک			مدیریت ریسک
		استراتژی مدیریت اطلاعات			مدیریت اطلاعات
استراتژی مدیریت BIM					مدیریت مدل‌سازی اطلاعات ساختمان (BIM)

Relevant comprehensive courses



آموزش نرم‌افزار EPPM با رویکرد
یکپارچه‌سازی سبد پروژه‌ها

<https://dralavipour.com/general-course/EPPM>



استراتژی برنامه‌ریزی و کنترل پروژه در طول
چرخه حیات پروژه

<https://dralavipour.com/video-course/web23>

Relevant comprehensive courses



<https://dralavipour.com/video-course/GC-scheduling>



<https://dralavipour.com/video-course/baseline-schedule>

Relevant comprehensive courses



Video Course

منحنی‌های پیشرفت پروژه (S-Curve)؛ انواع
+ تدوین + تحلیل + نکات کلیدی + سند
AACE

<https://dralavipour.com/video-course/s-curve>



Video Course

تدوین و تایید برنامه زمان‌بندی به‌روز شده
(Update Schedule)؛ اصول + نکات حیاتی +
چکلیست + سند AACE

<https://dralavipour.com/video-course/update-schedule>

Relevant comprehensive courses



<https://dralavipour.com/video-course/recovery-schedule>

Relevant comprehensive courses

**Strategy to Program Management
Next years...**

<https://dralavipour.com/general-course/strategic-program-management>

Relevant comprehensive courses

This is an ongoing list...

CM Roadmap – Management skills



منتورینگ (Management Skills) - سطح مدیریتی

سطح ۵	سطح ۴	سطح ۳	سطح ۲	سطح ۱
پیش‌نیاز ورود	پیش‌نیاز ورود	پیش‌نیاز ورود	پیش‌نیاز ورود	پیش‌نیاز ورود
داشتن مدرک مدیریتی سطح ۴	داشتن مدرک مدیریتی سطح ۳	داشتن مدرک مدیریتی سطح ۲	داشتن مدرک مدیریتی سطح ۱	دارای مدرک کارشناسی در زمینه مهندسی
تسلط بر مباحث مهارت‌های سخت و نرم سطح ۵	تسلط بر مباحث مهارت‌های سخت و نرم سطح ۴	تسلط بر مباحث مهارت‌های سخت و نرم سطح ۳	تسلط بر مباحث مهارت‌های سخت و نرم سطح ۲	تسلط بر مباحث مهارت‌های سخت و نرم سطح ۱

CM Roadmap – Consulting skills



مشاوران (Consulting Skills) - سطح مشاوره

سطح ۵	سطح ۴	سطح ۳	سطح ۲	سطح ۱
مدیریت درس آموخته‌های پروژه	مدیریت کیفیت پروژه	جلوگیری و حل اختلاف در پروژه	برنامه‌ریزی پروژه	
	مدیریت ایمنی پروژه	آنالیز و مدیریت ریسک پروژه	مدیریت تغییرات پروژه آنالیز و اجرای ساخت‌پذیری پروژه	

Relevant comprehensive courses



<https://dralavipour.com/general-course/consultplan1>

Relevant comprehensive courses

Constructability Analysis
Next years...

<https://dralavipour.com/general-course/constructability-analysis>



مدیریت پروژه‌های صنعت ساخت (ساختمانی، زیرساختی و صنعتی)

فصل پنجم: مدیریت مالی و هزینه
ارزیابی اقتصادی
مدیریت هزینه
مدیریت مالی
تامین مالی

ارائه دهنده:

سید محمدرضا علوی پور

(PhD, PMP, CMIT)

دانشگاه Illinois Tech آمریکا

What we will learn?

- ☐ Economic analysis
- ☐ Cost management
 - ❖ Estimating
 - ❖ Control
- ☐ Financial management
- ☐ Project financing
- ☐ Cm roadmap related to this section

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ECONOMIC ANALYSIS

Introduction

- ❑ **Construction firms** acquire funds, as most individuals do, by **borrowing money** from banks and similar lending sources.
- ❑ It is typical, for instance, to borrow money to **finance operations** in the field pending receipt of progress payments from the client.

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Introduction

- ❑ A **more long-term** variety of borrowing occurs when
 - ❖ Purchasing new equipment
 - ❖ Expanding staff
 - ❖ Move into a new geographical location or industry sector

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Construction managers and economic analysis

- ❑ The **management** of expensive, long-term construction projects definitely requires a **thorough understanding** of the principles and techniques of Economic Analysis and Financial Management.
- ❑ The **mathematical approach** of engineering economy is **increasingly useful** even for small, personal decisions.
- ❑ **Construction managers** need to have a **good working understanding** of the concepts of economic analysis and financial management.

Time value of money

- ☐ **One dollar** available **right now** is more attractive than one dollar offered to be available at a **future time**.
- ☐ A dollar **promised to be given a year from now** is more attractive than a dollar promised to be **given two years from now**.
- ☐ The **value of an amount of money**, therefore, depends on its
 1. Nominal
 2. When it is earned or paid out (effective)

This key concept is known as the **time value of money (TVM)**

Simple interest

Year (n)	Base for Applying i	Interest i for Period	Total Owed (F)
0 (now)			10,000
1	10,000	$10,000 \times 0.10 = 1,000$	11,000
2	10,000	$10,000 \times 0.10 = 1,000$	12,000
3	10,000	$10,000 \times 0.10 = 1,000$	13,000

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Compound interest

Year (n)	Base for Applying (i)	Interest for Period	Total Owed (F)
0 (now)			10,000
1	10,000	$10,000 \times 0.10 = 1,000$	11,000
2	11,000	$11,000 \times 0.10 = 1,100$	12,100
3	12,100	$12,100 \times 0.10 = 1,210$	13,310

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Nominal and effective rate

- ❑ Technically, rate can refer to any time unit, from **seconds to decades**.
- ❑ A lender could advertise a loan with a “**1% interest rate**” and then indicate in small print that it refers to **1% per week**.
- ❑ To protect consumers, Congress passed the **Truth in Lending Act in 1968**, which among other issues, requires that lenders clearly indicate interest rates as an **annual percentage** of each received dollar.
 - ❖ This annual percentage rate (APR) also includes upfront commissions and fees converted to **equivalent annual percentages**.

Equivalence and minimum attractive rate of return

- ❑ **Equivalence** is usually considered in terms of interest rates **instead** of total interest.
- ❑ If a person or company considers it **equally attractive** to have \$100 now or to get \$150 a year from now, the interest rate that this person considers **equivalent** would $\frac{\$50}{\$100} = 50\%$.
 - ❖ This particular interest rate is called the minimum attractive rate of return (MARR) for that person or company.
- ❑ In a **business environment**, a company's MARR is **not found** as **arbitrarily** as shown.

Equivalence and minimum attractive rate of return

- ☐ If the **company** works in heavy construction and in its **experience** a reasonable return on equity is 20%,

then it could **not aspire** to a 50% MARR.

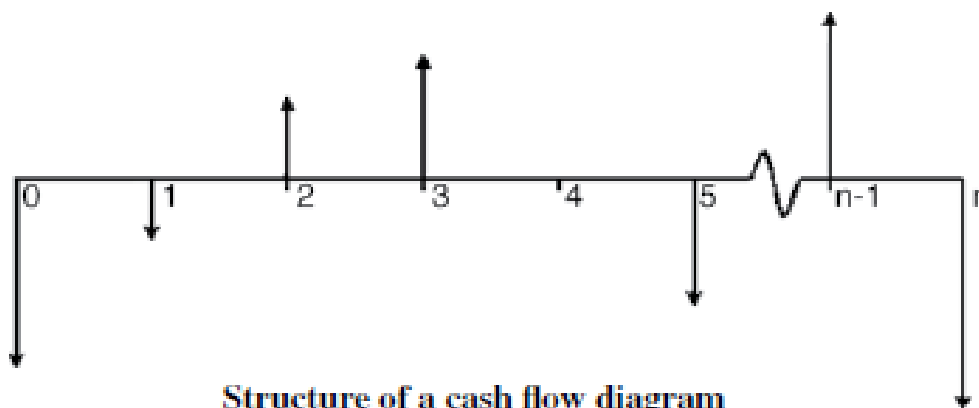
- ☐ Or, if it is **paying** a **10% interest rate** on its borrowed money,
then its MARR cannot be less than 10%.

- ☐ Inflation

- ☐ Risks

- ☐ ?

Cash flow diagrams



Structure of a cash flow diagram

Summary of equivalence formulas

1. Compound amount factor for P to F (F/P)
2. Present worth factor for F to P (P/F)
3. Compound amount factor uniform series for A to F (F/A)
4. Sinking fund factor for F to A (A/F)
5. Present worth factor uniform series for A to P (P/A)
6. Capital recovery factor for P to A (A/P)

Type of Cash Flow Name	Single Payment		Uniform Series (Annuities)			
	Compound Amount Factor	Present Worth Factor	Compound Amount Factor	Sinking Fund Factor	Present Worth Factor	Capital Recovery Factor
Description	Find F given P (F/P)	Find P given F (P/F)	Find F given A (F/A)	Find A given F (A/F)	Find P given A (P/A)	Find A given P (A/P)
Formula	$(1+i)^n$	$\frac{1}{(1+i)^n}$	$\frac{[(1+i)^n - 1]}{i}$	$\frac{i}{[(1+i)^n - 1]}$	$\frac{[(1+i)^n - 1]}{i \times (1+i)^n}$	$\frac{i \times (1+i)^n}{[(1+i)^n - 1]}$



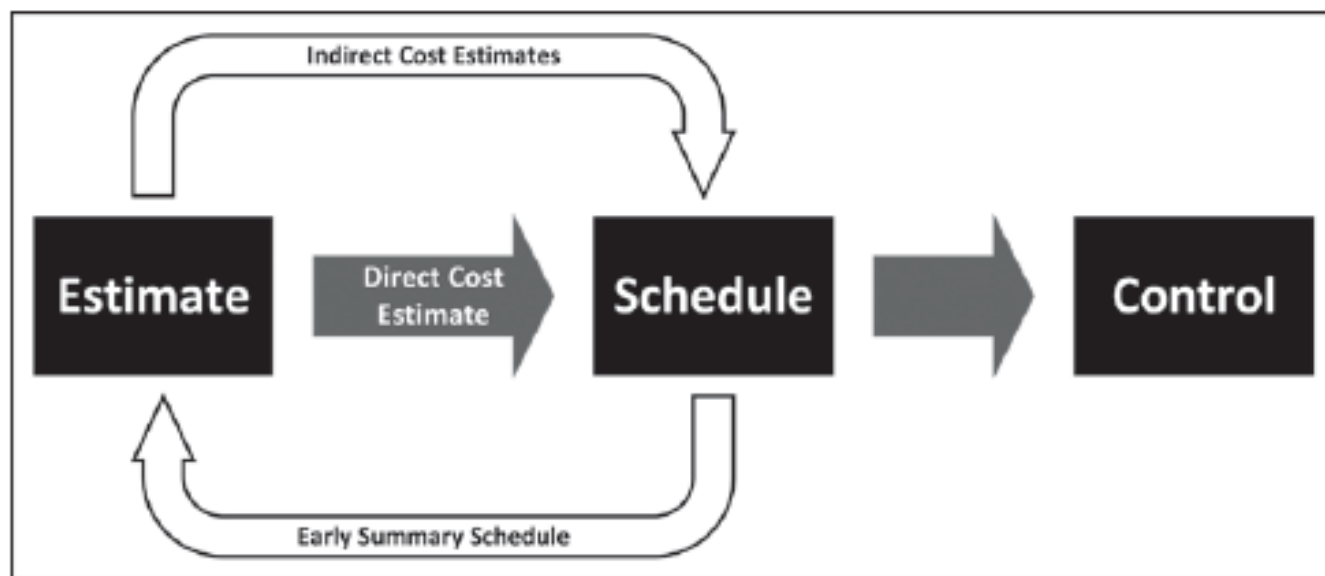
Sensitivity analysis

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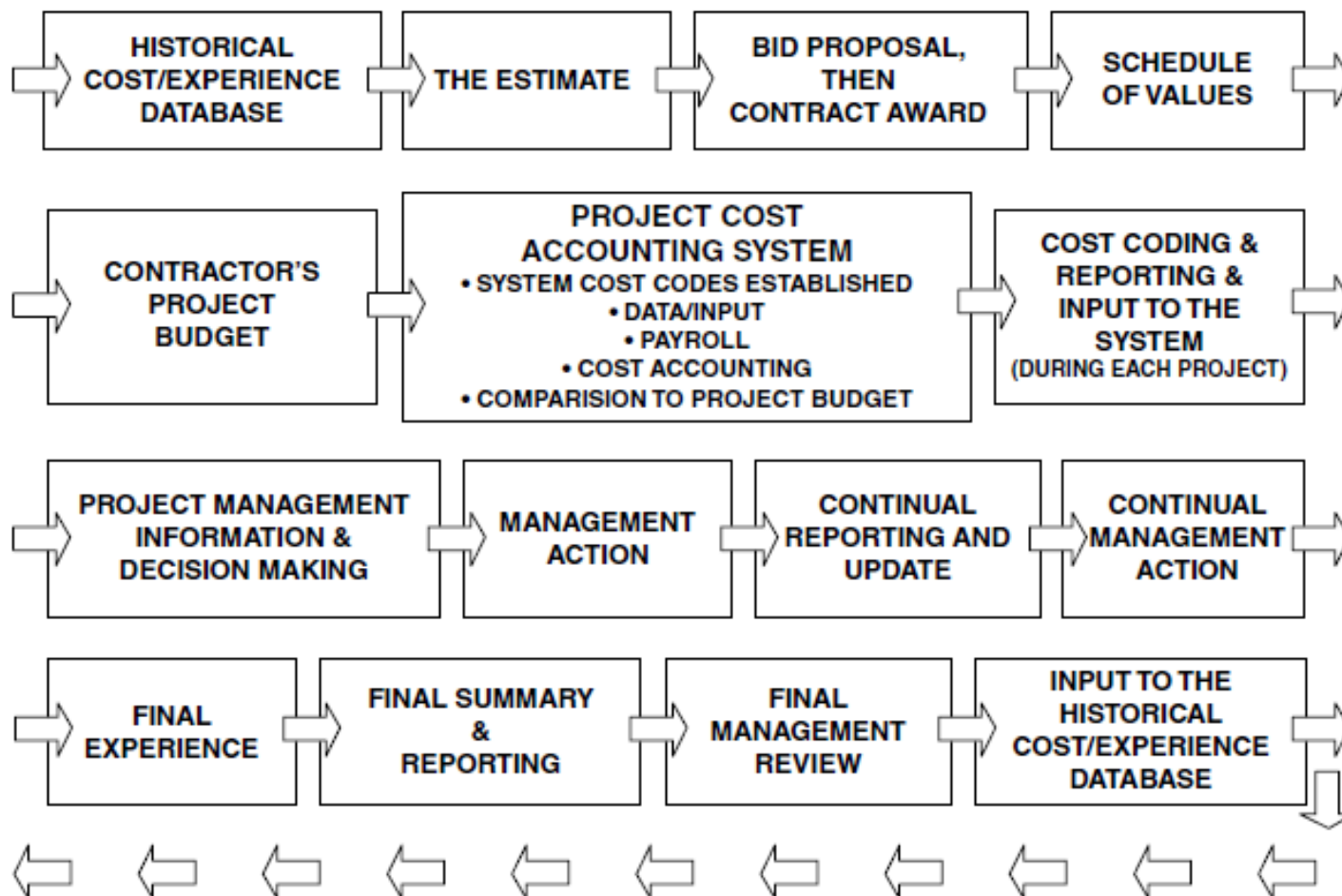
COST MANAGEMENT

(Estimating)

Project controls



Cost management cycle



Estimating project cost

❑ **Estimators** have an **awesome responsibility**.

1. First, they must come up with an accurate but competitive estimate that will win the job.
2. Second, their planning and calculations set the stage for the **overall management targets** for the entire project.

Once the **estimator turns** the project over to the project manager and the on-site team,
the **estimator shifts** to a **support role** and
really has **no direct management duties** associated with the day-to-day operations.

Estimating project cost

- ❑ Every person in construction management **must** be **familiar** with the estimating process, but **not everyone** in construction is suited to be an estimator.
- ❑ It takes **special skills** and aptitude to be successful at this **very important role** in construction management.

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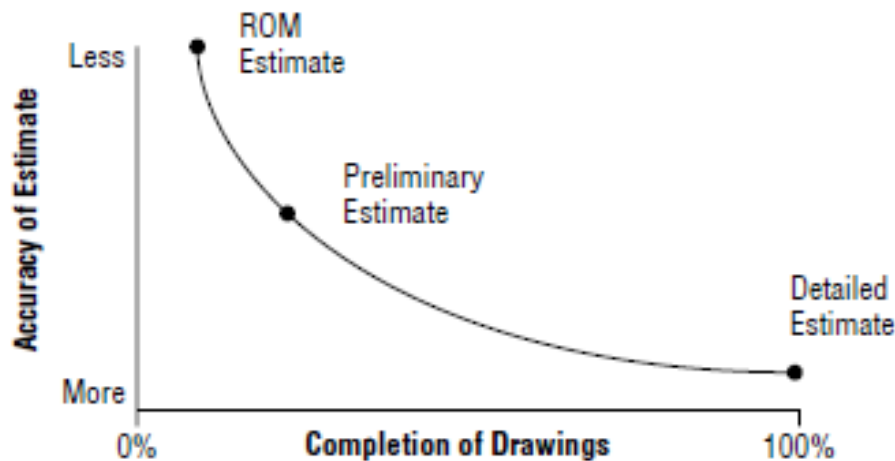
Estimating project cost

NOTE

When a job goes bust for the contractor with significant cost overruns, there is often an internal argument regarding who is to blame. The project manager may point to a bad estimate as the source of the failure. But the estimator may turn around and accuse the on-site team of poor management resulting in the overruns. This finger-pointing is usually a futile effort; the time would be better spent looking at specific areas of overrun and analyzing them, line item by line item, to see what mistakes should be avoided on the next project or estimate.

Types of estimates

- ☐ Conceptual estimates
- ☐ Preliminary estimates
- ☐ Detailed estimates



Estimate accuracies

<i>Type of estimate</i>	<i>Document development</i>	<i>Accuracy</i>
Budget or rough order of magnitude (ROM)	Schematics, design development, 30% construction documents	10–20%
Guaranteed maximum price for cost-plus projects	60%–90% construction documents	5%
Lump sum bid	100% plans and specifications	2%

Factors impacting project cost

- ☐ Project size
- ☐ Complexity
- ☐ Site location
- ☐ Time of construction
- ☐ Quality of work
- ☐ Market conditions management factors

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Types of costs – Direct costs

- ☐ Materials
- ☐ Labor
- ☐ Equipment
- ☐ Subcontractors

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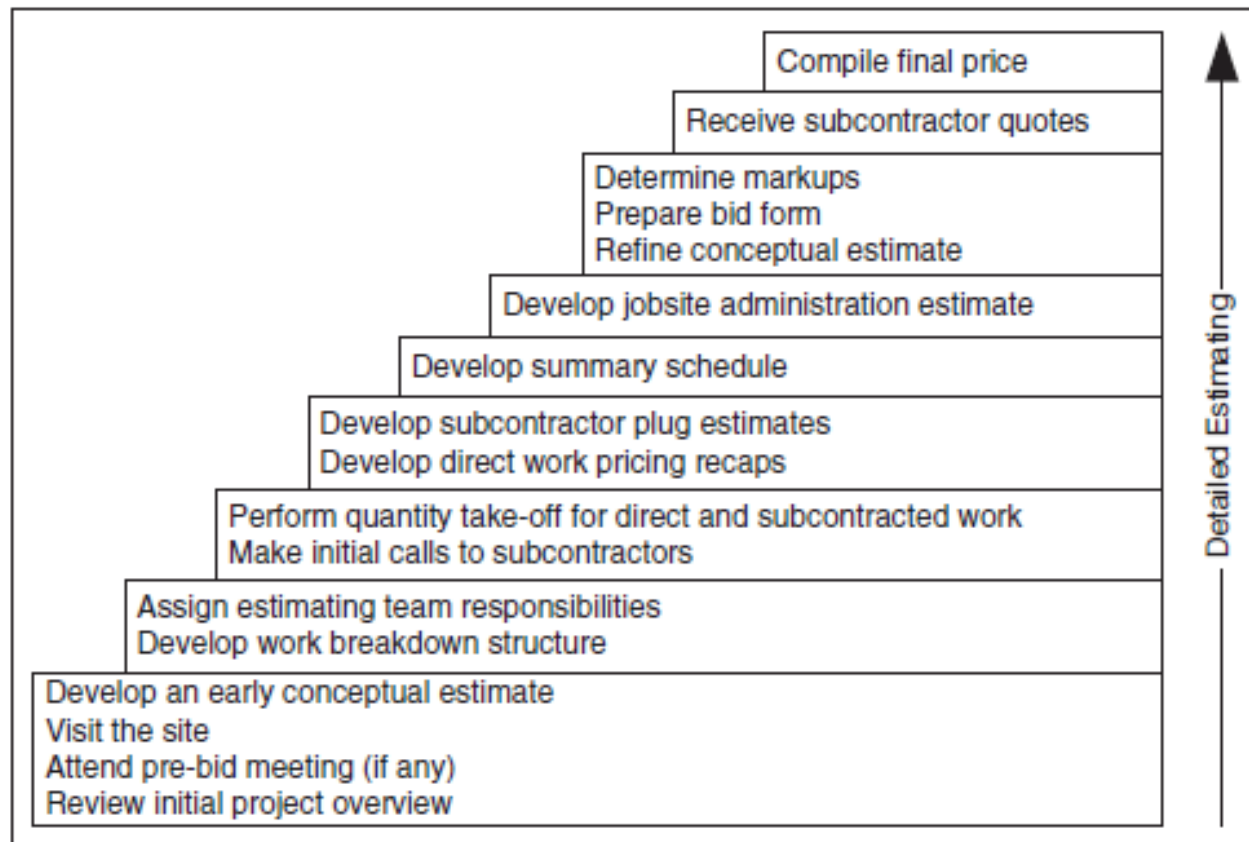


Types of costs – Indirect costs

- ☐ Supervision
- ☐ Job trailer expense
- ☐ Temporary utilities
- ☐ Testing and inspections
- ☐ Job photographs
- ☐ Safety suppliers
- ☐ Cleanup
- ☐ Bonds and insurance

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Estimating process



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موسسه مهندسی و مدیریت ساخت علوی پور (ACEMI)

دفتر آموزش



تهران، بلوار فردوس شرق، مجتمع آبگینه، طبقه سوم اداری، واحد C42



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