Construction Management

Short notes for B.Tech Civil · GATE CE

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1. Introduction

- **Construction management** = planning, organising, directing and controlling resources (men, materials, machines, money, time) to finish a project on time, within budget and with quality.
- Project life cycle: concept → feasibility → design → tender → construction → handover / operation.
- Stakeholders: owner (client), consultant / architect, contractor, sub-contractors, suppliers, government bodies.

➤ Functions of management

1. **Planning**: what to do, how, and in what order.
2. **Scheduling**: putting the plan on a time scale.
3. **Organising**: assigning people and resources.
4. **Directing** and **controlling**: monitoring progress and correcting deviations.

2. Bar Charts and Milestone Charts

- **Bar chart (Gantt chart)**: activities on the vertical axis, time on the horizontal axis, a bar for each activity.
- Simple and easy to understand; good for small projects and for showing progress.

➤ Limitations of bar charts

- Do not show dependencies between activities.
- Cannot show critical activities or float.
- Not useful for large, complex projects; hard to update.
- No uncertainty in time.
- **Milestone chart**: bar chart with key events (milestones) marked; still does not show interdependency clearly.

3. Network Basics

- **Activity**: a task that uses time and resources (shown by an arrow in AOA).
- **Event (node)**: start or end of activities; uses no time.
- **Dummy activity**: zero time, shows a logical link only (dashed arrow).
- Network types: **AOA** (activity on arrow) and **AON** (activity on node; precedence diagram).

➤ Rules for drawing networks

- Each activity has one tail and one head event; time flows left to right.
- No loops (cycles) and no dangling activities.
- Fulkerson's rule is used for numbering events (tail number < head number).

> **REMEMBER** Dummies are used for two reasons: to show correct logic, and to avoid two activities having the same start and end events.

4. Critical Path Method (CPM)

- CPM is deterministic and activity-oriented. Used for repetitive works with known durations (buildings, roads).
- **Critical path** = longest path through the network. It gives the project duration. Critical activities have zero total float.

➤ Time terms

Term	Meaning
EST	Earliest start time (from forward pass)
EFT	EST + duration
LFT	Latest finish time (from backward pass)
LST	LFT − duration

- **Forward pass**: TE of an event = max of (TE of tail + duration) over incoming activities.
- **Backward pass**: TL of an event = min of (TL of head − duration) over outgoing activities.

Floats

FORMULA Total float TF = LST − EST = LFT − EFT = TL(head) − TE(tail) − t.

FORMULA Free float FF = TE(head) − TE(tail) − t. Independent float IF = TE(head) − TL(tail) − t. Interfering float = TF − FF.

- Always: IF ≤ FF ≤ TF. Negative IF is taken as zero.
- **Slack** is the float of an event (TL − TE); used in PERT.

Solved example

Network: A (1-2) = 4, B (1-3) = 3, C (2-4) = 5, D (3-4) = 4, E (4-5) = 2 days.

- Forward pass: TE1 = 0, TE2 = 4, TE3 = 3, TE4 = max(4 + 5, 3 + 4) = 9, TE5 = 11.
- Backward pass: TL5 = 11, TL4 = 9, TL3 = 9 − 4 = 5, TL2 = 9 − 5 = 4, TL1 = 0.

Activity	t	EST	EFT	LST	LFT	TF	FF
A (1-2)	4	0	4	0	4	0	0
B (1-3)	3	0	3	2	5	2	0
C (2-4)	5	4	9	4	9	0	0
D (3-4)	4	3	7	5	9	2	2
E (4-5)	2	9	11	9	11	0	0

- Critical path: A–C–E, project duration = 11 days. B and D share 2 days of float.

5. PERT

- PERT is probabilistic and event-oriented. Used for new, one-time projects (research, defence) where durations are uncertain.
- Three time estimates: optimistic (to), most likely (tm), pessimistic (tp). Durations follow the **beta distribution**.

FORMULA Expected time te = (to + 4 tm + tp) / 6. Standard deviation σ = (tp − to) / 6. Variance = σ^2.

- Project duration follows the **normal distribution** (central limit theorem). Project variance = sum of variances of critical activities.

FORMULA Probability of finishing by Ts: Z = (Ts - Te) / σcp, then read probability from normal table.

EXAMPLE Activity with to = 4, tm = 6, tp = 14 days. te = (4 + 24 + 14)/6 = 7 days. σ = (14 - 4)/6 = 1.67 days. Project: Te = 30 days, σcp = 3 days. Probability of finishing in 33 days: Z = (33 - 30)/3 = 1, probability = 84.1%.

CPM	PERT
Deterministic (one time estimate)	Probabilistic (three time estimates)
Activity-oriented	Event-oriented
Float of activities	Slack of events
Includes time–cost trade-off (crashing)	Mainly time; no cost focus
Repetitive construction	Research / new projects

REMEMBER Z = 0 gives 50% probability; Z = 1 about 84%; Z = 2 about 97.7%; Z = -1 about 16%.

6. Time–Cost Trade-off (Crashing)

- **Direct cost** (labour, materials, equipment) rises when duration is reduced.
- **Indirect cost** (overheads, supervision, penalties) falls when duration is reduced.
- **Optimum duration** = where total cost (direct + indirect) is minimum.

FORMULA Cost slope = (crash cost - normal cost) / (normal time - crash time).

EXAMPLE Normal: 10 days, Rs 20,000. Crash: 7 days, Rs 29,000. Cost slope = (29000 - 20000)/(10 - 7) = Rs 3,000 per day.

➤ Crashing steps

1. Find the critical path with normal durations.
2. Crash the critical activity with the lowest cost slope, one day at a time.
3. Watch for new critical paths; when there are parallel critical paths, crash them together.
4. Stop when total cost starts rising or all critical activities reach crash time.

➤ Resource management

- **Resource smoothing**: keeps project duration fixed; uses float to reduce peaks.

- **Resource levelling**: resource limit is fixed; project duration may increase.
- Resource histogram shows daily demand of a resource.

7. Construction Equipment

Equipment	Use
Bulldozer	Pushing earth over short distances, clearing
Scraper	Excavating, hauling and spreading (medium haul)
Power shovel	Excavation above machine level
Backhoe (hoe)	Excavation below machine level (trenches)
Dragline	Loose / wet soil, long reach, below level
Clamshell	Vertical digging, loading into hoppers
Tower / mobile cranes	Lifting materials
Rollers	Compaction

- **Production** of an excavator = bucket capacity × fill factor × cycles per hour × efficiency.
- Owning cost (depreciation, interest, insurance) + operating cost (fuel, operator, repairs).

➤ Depreciation methods

FORMULA Straight line: D = (C - S) / n per year. Sum of years digits: Dm = (n - m + 1) / [n(n + 1)/2] x (C - S).

- Declining balance: fixed % of book value each year. Sinking fund: uniform deposits that grow with interest to replace the asset.

EXAMPLE Machine cost Rs 10 lakh, salvage Rs 1 lakh, life 5 years. Straight line: (10 - 1)/5 = Rs 1.8 lakh per year. Sum of years digits, year 1: 5/15 x 9 = Rs 3 lakh.

8. Engineering Economics, Contracts and Quality

Time value of money

FORMULA Compound amount $F = P(1 + i)^n$. Present worth $P = F / (1 + i)^n$. Annuity present worth $P = A[(1 + i)^n - 1] / [i(1 + i)^n]$.

- Comparison methods: present worth, annual worth, rate of return (IRR), benefit–cost ratio, payback period.
- **Break-even point** = fixed cost / (price − variable cost per unit).

Contracts and tendering

Contract type	Feature
Lump sum	Fixed total price for defined work
Item rate (unit rate)	Payment per quantity of each item (most common in PWD)
Percentage rate	Contractor quotes % above / below schedule rates
Cost plus	Actual cost + fee; used for urgent / unclear works
EPC / turnkey	One firm designs, procures and builds
BOT / PPP	Private party builds, operates, then transfers

- Tender process: notice inviting tender → sale of documents → pre-bid meeting → bids with EMD → opening → evaluation → letter of acceptance → agreement (with security deposit).
- Disputes: negotiation, mediation, arbitration (Arbitration and Conciliation Act, 1996), court.

Quality, safety and monitoring

- **Quality control** = inspection and testing; **quality assurance** = planned system to prevent defects. TQM involves everyone.
- Safety: PPE, scaffolding checks, excavation support, safety officer, toolbox talks.
- **Earned value management**: CV = EV − AC, SV = EV − PV, CPI = EV / AC, SPI = EV / PV (less than 1 means over budget / behind schedule).

9. Most Asked Questions (practice)

1. What are the limitations of bar charts? How do networks overcome them?
2. Explain dummy activities and Fulkerson's rule with an example.
3. Draw a network, find the critical path and all floats.
4. Differentiate CPM and PERT.
5. Find expected time, variance and probability of completion in PERT.
6. Explain time–cost trade-off; find the optimum duration by crashing.
7. Differentiate resource smoothing and levelling.
8. Explain selection of excavating equipment; find excavator output.
9. Find depreciation by straight line and sum-of-years-digits methods.
10. Explain types of contracts and the tendering process.

TIP In GATE CE, network floats, PERT probability (2 values) and crashing cost slope are asked almost every year. Practise forward and backward pass until you can do it in 2 minutes.