Embracing and Extending Project Management Techniques: CPM and PERT along with Theory of Constraints (TOC) for Effective Management of the Mangalore Metro

A TEACHING CASE

SENTHILKUMAR A

FOUNTAINHEAD GLOBAL

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Background

The city of Mangalore, a prominent coastal hub in Karnataka, is facing increasing pressure on its public transportation system due to rapid urban growth and vehicular congestion. To address this, the government has proposed the Mangalore Metro Project, an elevated rapid transit corridor designed to provide a sustainable and efficient public transport alternative.

The proposed Phase I spans 20 kilometers and includes 16 elevated stations, a central depot, and integration points with the Mangalore airport and city bus network. The project is targeted to be completed in 36 months. Given the scale, coordination across multiple agencies, and the risks of delays, robust project planning methods are critical.

This case presents a hypothetical but realistic opportunity for students to embrace and extend Critical Path Method (CPM) and Program Evaluation Review Technique (PERT) to simulate and manage such a complex infrastructure project while at the same time extinguishing lack of recognition of Project managers.

Project Scope Summary

- **Corridor Length:** 20 km (elevated)
- **Stations:** 16
- **Key Depot Location:** Kulasekhara
- **Possible Integration Points:** Airport, Thumbe/Kannur, KSRTC terminal, Ullal,/Thokkotu, Hoggie Bazaar, Baikampady Industrial area
- **Execution Timeframe (Target):** 36 months

Objectives of the Case Study

1. Apply PERT to calculate expected project durations and understand uncertainty.
2. Use CPM to determine the critical path and identify project bottlenecks.
3. Evaluate slack in non-critical activities and discuss project flexibility.
4. Compute Z-score to estimate the probability of on-time project completion.

5. Explore time-cost trade-offs and the potential role of Theory of Constraints (TOC).

Based on the background details of Mangalore Metro, the program evaluation and review technique (PERT) can be applied as in the below table

Project Activities and Time Estimates

ID	Activity	Predecessor(s)	Time Estimates (months)
A	Land Acquisition	–	O=4, M=6, P=10
B	Utility Shifting	A	O=1, M=2, P=3
C	Soil Testing & Survey	A	O=2, M=3, P=5
D	Foundation & Piling	B, C	O=4, M=6, P=8
E	Pier & Viaduct Construction	D	O=10, M=12, P=15
F	Station Box Work (16 stations)	D	O=5, M=6, P=9
G	Depot Construction	D	O=6, M=8, P=10
H	Track Laying	E	O=4, M=5, P=6
I	Signaling & Telecom Setup	F	O=2, M=3, P=6
J	Rolling Stock Procurement	A	O=6, M=8, P=10
K	System Integration	H, I, J	O=3, M=4, P=6
L	Trial Runs & Safety Certification	K	O=1, M=2, P=3

TABLE 1

The network diagram is give below(Figure 1)

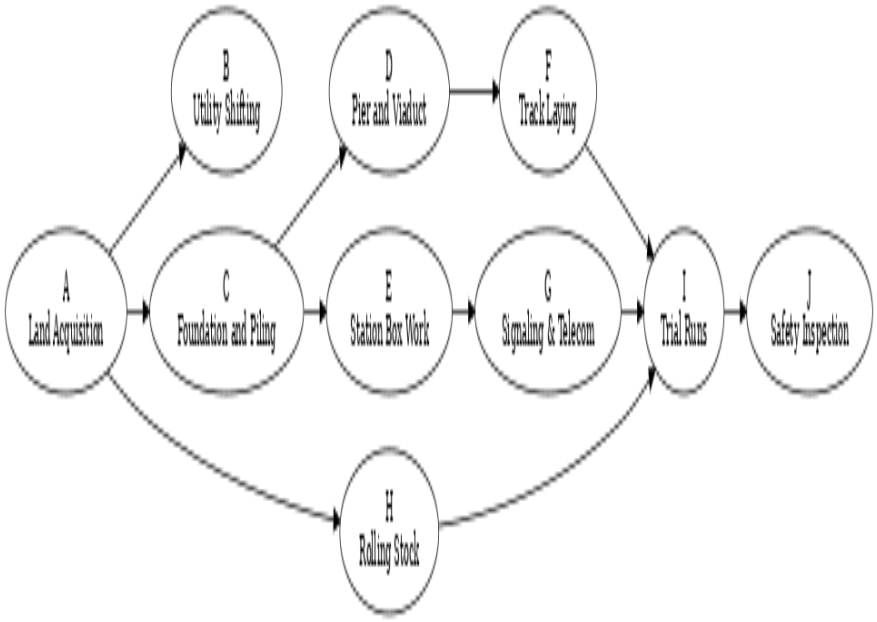

Figure 1

Key Analysis Results (Summary)

- **Critical Path:** A → C → D → F → I → J
- **Expected Project Duration:** 35.83 months
- **Standard Deviation:** 1.555 months
- **Probability of Completion within 37 Months:** 77.34%

TOC Application in Mangalore Metro

1. Identifying the Constraint:

- The critical path (A → C → D → F → I → J) represents the system constraint. TOC views this as the drum.

2. Buffer Management:

- Introduce a project buffer of 2 months before activity K to increase the confidence of completing within 37 months.
- Feeding buffers can be added before activity D from B and C.

3. Exploiting and Subordinating:

- Align all support and resource allocation to keep critical activities on schedule.

4. Elevating the Constraint:

- Consider crashing or reallocating resources to station box work (F) or signaling setup (I).

5. Drum-Buffer-Rope Configuration:

- **Drum:** Activity F – Station Box Work
- **Buffer:** Inserted before K
- **Rope:** Monitoring and signaling from system integration team

6. Continuous Improvement:

- TOC recommends dynamic reallocation of resources as buffer consumption trends are monitored in real time.

Conclusion

This case enables students to connect theoretical project management concepts with a real-world infrastructure problem. It encourages the use of quantitative tools (CPM, PERT, Z-score) along with strategic thinking on resource constraints and coordination challenges. It also sets the stage for integrating traditional tools with modern PM methods like Agile, TOC, and data-driven dashboards.

This case is ideal for courses in Operations Management, Infrastructure Planning, or Engineering Project Management, and is suitable for classroom discussions, assignments, or competition presentations.

Teaching Notes

Target Audience: MBA, M.Tech, or senior undergraduate students in project management, operations, or construction engineering.

Time Required: 60–90 minutes classroom session

Teaching Objectives:

- Understand and apply CPM and PERT to a real-world infrastructure project.
- Evaluate uncertainty using PERT and probabilistic models.
- Encourage discussion on managerial decision-making under constraints.
- Apply Theory of Constraints for managing large-scale public projects.

Suggested Flow:

1. Brief project introduction and background (10 mins)
2. Group work: Build network and compute critical path/TE/variance (25 mins)
3. Instructor-led discussion: Slack, crashing, Z-score interpretation (20 mins)
4. Open discussion: Decision trade-offs, TOC, Agile integration (15 mins)
5. Wrap-up with takeaways and applications (10 mins)

Assessment Opportunities:

- Short write-up on project risk handling
- Group presentation of findings
- Quiz on CPM/PERT logic and calculations

Discussion Questions

1. What is the significance of identifying the critical path in the Mangalore Metro project?
2. How can project managers use float/slack information in decision-making?
3. Given the Z-score analysis, how should managers plan buffers?
4. Should activity E (viaduct construction) be crashed to save time?
5. How could Theory of Constraints improve on CPM/PERT in this case?
6. What would be the drum-buffer-rope configuration for Mangalore Metro?
7. How does TOC view project completion risk differently than PERT?

Teaching Aids Provided

- Network Diagram (AON format)
- CPM/PERT calculation tables (TE, variance, slack)
- Z-score computation sheet
- Discussion questions and extension topics

Instructor Tips:

- Prepare a pre-drawn AON network to speed up class time.
- Allow groups to argue different critical paths if assumptions vary.
- Use software tools (Excel, MS Project) for bonus/demonstration.
- Introduce public-private partnership (PPP) model as advanced layer.
- Encourage students to critique CPM vs TOC assumptions in project management.