International Journal Publishing
INFLUENCE: International Journal of Science Review
Volume 8, No. 2, 2026
https://influence-journal.com/index.php/influence/index

Critical Path Analysis of an Automotive Engine Laboratory Construction Project

Muhammad Alfian Hafidzin[1], Asep Hermawan[2], Yayan Heru Haerudin[3]
[1,2,3]Sekolah Tinggi Teknologi Wastukancana, Purwakarta, Indonesia
Email: muhammadalfian06@gmail.com

Abstract. Construction schedules presented only as bar charts provide limited information on logical dependencies, time flexibility, and the activities that govern project completion. This study evaluates the schedule of an automotive engine laboratory construction project using the Critical Path Method (CPM). Case data were consolidated from schedule documents, field observations, interviews, and project documentation into eleven work activities and one completion milestone. An Activity-on-Node network was developed and evaluated through forward-pass, backward-pass, and total-float calculations. The CPM model produced a 17-week project duration, equal to the company's original target, while revealing two critical paths: A-B-C-D-I-J-L and A-B-C-D-I-K-L. Steel erection and roofing each had two weeks of total float, whereas wall work and painting each had one week. Seven of the eleven executable activities were critical, and the two critical paths shared a 13-week common sequence. These findings demonstrate that CPM contributes not only through schedule compression but also by exposing schedule logic, focusing managerial attention, and identifying near-critical work that can become critical after a small deviation. The model is deterministic and does not incorporate resource constraints; therefore, subsequent schedule development should integrate resource leveling and probabilistic risk analysis.

Keywords: *Critical Path Method, Construction Scheduling, Project Control, Total Float, Activity-on-Node.*

A. INTRODUCTION

Schedule management converts project scope into a time-phased and logically connected execution model. International project-management guidance emphasizes that a reliable schedule should represent the complete scope, identify activity logic, calculate a valid critical path, and support periodic control (Kammouh, 2022; Standardization, 2020). In construction projects, these requirements are particularly important because structural, architectural, electrical, equipment-installation, and finishing activities interact across limited work areas and shared resources.

Bar charts remain useful for communicating planned start and finish periods, but they do not by themselves explain why an activity starts at a particular time or how a delay will propagate through the project. A network-based schedule addresses this limitation by explicitly representing predecessor-successor relationships (Jaber et al., 2018; Lee & Shvetsova, 2019; Marit et al., 2020). CPM then determines early and late dates, total float, and the longest path to completion. Contemporary studies have extended CPM toward dynamic mitigation, resource-constrained scheduling, and uncertainty analysis (Dalouchei, 2022; Hasan, 2024; Institute, 2019, 2021; Kim, 2020; Kostrzewa-Demczuk, 2024). Nevertheless, the deterministic CPM remains a practical first-stage method when a project has one accepted duration estimate for each activity and limited scheduling data.

Previous case studies in Indonesia have applied CPM to apartments, hospitals, roads, and small buildings, commonly reporting a shorter calculated duration than the initial schedule (Habibi, 2023; Husna, 2022; Saputra, 2021; Sholahuddin, 2024; Ulfa, 2021). However, an equal duration between the initial schedule and the CPM result should not be interpreted as a null result. A network model may still improve schedule quality by revealing multiple critical paths, near-critical branches, and the amount of time flexibility available to noncritical activities. This control-oriented value is relevant to small industrial facilities that combine civil work, steel erection, electrical systems, and machine installation but are initially managed through a weekly bar chart.

This study examines an automotive engine laboratory construction project in Karawang Regency, West Java, Indonesia. The original company schedule targeted completion in 17 weeks but did not explicitly identify the dependency network, activity float, or critical work. The study aims to construct an Activity-on-Node (AON) network, calculate the CPM parameters, identify critical and near-critical paths, compare the network result with the original target, and formulate schedule-control priorities. The main contribution is a transparent demonstration that CPM can enhance managerial visibility even when it does not shorten the nominal project duration.

B. METHOD

1. Research Design and Data Sources

A descriptive quantitative case-study design was used. The unit of analysis was the project schedule, represented by activity descriptions, deterministic durations, and finish-to-start dependencies. Primary information was obtained through field observation and semi-structured discussions with personnel involved in project coordination and execution. Secondary information included the weekly schedule, activity lists, project documents, and available workforce data.

The source records contained different levels of detail; therefore, the analysis used a consolidated dataset assembled from the consistent activity durations and logic adopted for the final schedule model. The dataset comprised eleven executable activities and one zero-duration completion milestone. Durations were expressed in weeks. The model should consequently be interpreted as a deterministic scheduling scenario derived from the available project records rather than as a resource-loaded or probabilistic forecast.

Table 1. Consolidated Activity Dataset

Code	Activity	Duration (Weeks)	Predecessor
A	Preparation work	2	-
B	Earthwork	2	A
C	Pile-cap excavation and casting	4	B
D	Sloof and floor casting	2	C
E	Steel erection	1	D
F	Wall work	4	D
G	Roofing	4	E
H	Painting	2	F
I	Electrical work	3	D
J	Machine installation	4	I
K	Finishing work	4	I
L	Project completion milestone	0	G, H, J, K

2. Analytical Procedure

The analytical procedure followed eight steps: data consolidation, Work Breakdown Structure development, activity coding, AON network construction, forward-pass calculation, backward-pass calculation, total-float and path analysis, and comparison with the company's 17-week target. Figure 1 summarizes the procedure.

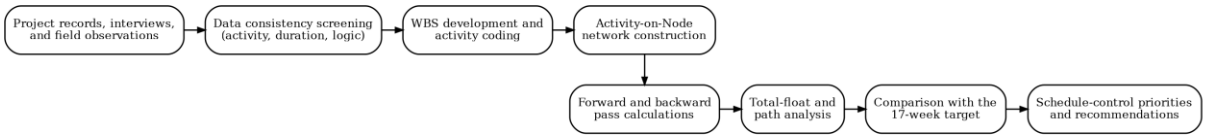

Figure 1. Research and CPM analysis procedure

For an activity i with duration d_i, the earliest finish was calculated using (1). When an activity had more than one predecessor, its earliest start was the maximum earliest finish among all predecessors, as shown in (2).

$$EF_i = ES_i + d_i \quad (1)$$

$$ES_i = max(EF_j), j \in Pred(i) \quad (2)$$

The backward pass started from the project completion time. The latest start was calculated using (3), while the latest finish for an activity with multiple successors was the minimum latest start among its successors, as shown in (4). Total float was calculated using (5). An activity was classified as critical when TF = 0. Activities with TF = 1 week were treated as near-critical because a small deviation could eliminate their remaining flexibility [2], [8].

$$LS_i = LF_i - d_i \quad (3)$$

$$LF_i = min(LS_k), k \in Succ(i) \quad (4)$$

$$TF_i = LS_i - ES_i = LF_i - EF_i \quad (5)$$

3. Scope and Analytical Limitations

The analysis focused on schedule logic and time. It did not evaluate cost crashing, resource leveling, productivity uncertainty, weather, design change, or material-delivery risk. CPM assumes that the resources required by concurrently scheduled activities are available; therefore, the calculated dates require a separate constructability and resource-feasibility review before field implementation (Dalouchei, 2022; Kim, 2020).

C. RESULT AND DISCUSSION

1. Network Structure and Project Duration

The AON network contains a four-activity common trunk (A-B-C-D) followed by three parallel work streams. The steel stream consists of E-G, the architectural stream consists of F-H, and the electrical/equipment stream begins with I and then divides into J and K. All streams converge at the completion milestone L. Figure 2 presents the network. Bold lines show the two critical routes, whereas dashed lines show noncritical branches.

The forward pass produced an earliest project completion of 17 weeks. The common sequence A-B-C-D consumed 10 weeks. Electrical work then extended the common critical sequence to week 13, after which machine installation and finishing independently required four weeks. The result demonstrates that electrical work is a high-leverage interface: a delay in activity I affects both downstream critical branches simultaneously.

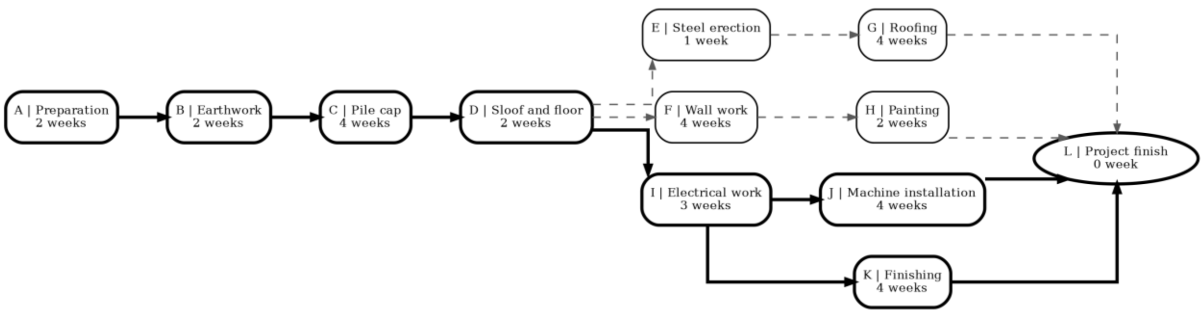

Figure 2. Activity-on-Node network and Critical Routes

2. Forward Pass, Backward Pass, and Total Float

Table 2 summarizes the CPM results. Seven of the eleven executable activities (63.6%) had zero total float: A, B, C, D, I, J, and K. The completion milestone L was also critical. E and G each had two weeks of total float, while F and H each had one week. The one-week float on the F-H stream means that this branch is near-critical rather than operationally unimportant.

Table 2. CPM Calculation Results

Code	Dur.	ES	EF	LS	LF	TF	Status
A	2	0	2	0	2	0	Critical
B	2	2	4	2	4	0	Critical
C	4	4	8	4	8	0	Critical
D	2	8	10	8	10	0	Critical
E	1	10	11	12	13	2	Noncritical
F	4	10	14	11	15	1	Near-critical
G	4	11	15	13	17	2	Noncritical
H	2	14	16	15	17	1	Near-critical
I	3	10	13	10	13	0	Critical
J	4	13	17	13	17	0	Critical
K	4	13	17	13	17	0	Critical
L	0	17	17	17	17	0	Critical milestone

Total float should be interpreted at the path level as well as the activity level. For example, E and G are on the same branch; their individual two-week float values are not additive. If E consumes the entire two-week allowance, G no longer retains an independent additional two weeks. This shared-float property is important when supervisors authorize delays or transfer resources between activities.

3. Critical and Near-Critical Path Analysis

Four complete routes connect project start and finish. Their durations are listed in Table 3. The two 17-week routes are critical. They share A-B-C-D-I, a 13-week common sequence representing 76.5% of the total project duration. Consequently, management attention should be concentrated first on the common trunk rather than distributed equally across all project activities.

Table 3. Complete Path Durations

No.	Path	Duration (Weeks)	Interpretation
1	A-B-C-D-E-G-L	15	Noncritical; 2-week margin
2	A-B-C-D-F-H-L	16	Near-critical; 1-week margin
3	A-B-C-D-I-J-L	17	Critical
4	A-B-C-D-I-K-L	17	Critical

The presence of two critical paths increases schedule sensitivity because progress must be protected on both J and K. However, the branches are not independent in managerial terms: they share the electrical predecessor I. A delay in I immediately shifts both critical branches, whereas a delay in only J or K affects one branch. The F-H path is also important because one week of delay would make it co-critical; any delay beyond one week would postpone project completion. This interpretation is consistent with recent research emphasizing that subcritical paths can contain meaningful schedule risk even when their deterministic float is positive [8].

4. Comparison with the Original Schedule

The CPM result did not reduce the original 17-week target. Nevertheless, the analytical output was substantially richer than the initial weekly bar chart. The initial schedule communicated timing, while the network model explained logic, exposed the two critical paths, quantified float, and established a rational basis for surveillance. Similar case studies have often reported shorter CPM durations (Sholahuddin, 2024; Ulfa, 2021); the present case shows a different but practically important outcome: the method can validate a target duration while transforming a static display into a control model.

Table 4. Original Bar Chart Versus CPM Schedule Model

Indicator	Original Bar Chart	CPM Model
Project duration	17 weeks	17 weeks
Dependency logic	Not explicit	Explicit AON logic
Critical paths	Not identified	Two 17-week paths
Time flexibility	Not quantified	TF = 0-2 weeks
Near-critical work	Not identified	F-H path; 1-week float
Control priority	General monitoring	A-B-C-D-I-J/K and F-H

5. Managerial Implications and Proposed Schedule Controls

The common critical sequence should be controlled through milestone-based readiness reviews. Preparation should be completed by the end of week 2, earthwork by week 4, pile-cap work by week 8, sloof and floor work by week 10, electrical work by week 13, and machine installation and finishing by week 17. Materials, drawings, access, and labor for each critical activity should be confirmed before its planned start rather than after a delay becomes visible.

Activities E, F, and I are scheduled to start after D, while J and K are scheduled to start after I. This planned concurrency is the primary reason the sum of individual activity durations exceeds the 17-week project duration. Before implementation, the project team must confirm that concurrent work packages use separate crews, have compatible work zones, and do not create safety or access conflicts. Resource-constrained studies show that a time-feasible CPM schedule may become infeasible when labor and equipment availability are imposed (Dalouchei, 2022; Kim, 2020).

The schedule should be updated at least weekly. Any change in activity duration or logic requires recalculation of the critical path because criticality can migrate as work progresses [4]. Float consumption on E-G and F-H should be recorded explicitly. A one-week deviation on the F-H branch should trigger escalation because the branch would become critical, while a two-week deviation on E-G would exhaust all remaining margin.

Table 5. Recommended Schedule-Control Priorities

Activity/Path	Schedule Significance	Recommended Control
A-B-C-D	Protect the 10-week common trunk	Weekly milestone review; confirm drawings, materials, and access before start
I	Feeds both critical branches	Complete electrical prerequisites by week 13; prevent interface rework
J and K	Parallel critical branches	Use separate accountable teams and coordinate shared work areas
F-H	One-week near-critical margin	Escalate any one-week variance and prevent additional float consumption
E-G	Two-week noncritical margin	Use float deliberately; do not assume E and G have additive allowances
Entire Network	Critical path may change	Update actual dates and recalculate CPM every reporting period

6. Limitations and Future Development

The principal limitation is the deterministic and aggregated nature of the dataset. Several work packages combine multiple field operations, and all relationships are represented as finish-to-start. A more detailed schedule could divide electrical work into rough-in, cabling, panel installation, and testing; divide machine installation into delivery, positioning, anchoring, connection, and commissioning; and model overlapping work through start-to-start or finish-to-finish relationships where technically justified.

The model also excludes resource restrictions, activity-duration uncertainty, weather, material lead times, and cost. These omissions do not invalidate the CPM arithmetic, but they limit the result to a logic-based baseline. Future research should validate the detailed activity logic with project personnel, load labor and equipment requirements, apply resource leveling, and conduct Monte Carlo or PERT-based schedule-risk analysis. Such extensions would test the robustness of the 17-week target and identify whether the deterministic critical paths remain critical under uncertainty (Gaspar et al., 2022; Pantis et al., 2024).

D. CONCLUSION

The Critical Path Method converted the automotive engine laboratory project's 17-week bar chart into a logic-driven schedule model. The analysis identified two critical paths, A-B-C-D-I-J-L and A-B-C-D-I-K-L, and showed that seven of eleven executable activities had zero total float. Steel erection and roofing retained two weeks of float, while wall work and painting retained only one week and therefore formed a near-critical path. Although CPM did not shorten the nominal project duration, it clarified the sequence of work, revealed that the two critical paths shared a 13-week common trunk, and established specific priorities for milestone control and float management. The results support the use of CPM as a schedule-transparency and control tool, not merely as a duration-reduction technique. Before implementation, the schedule should be verified at a more detailed activity level and tested against labor, equipment, workspace, and uncertainty constraints. Resource loading and probabilistic schedule-risk analysis are recommended as the next stages of development.

REFERENCES

Dalouchei, F. (2022). A bi-objective model for scheduling construction projects using critical chain method and interval-valued fuzzy sets. *Buildings*, *12*(7), 904. https://doi.org/10.3390/buildings12070904

Gaspar, D. J., George, A., McCormick, R. L., & Wagner, R. M. (2022). *Building and Executing Aggressive Research Plans in a Large National Laboratory Consortium: Insights from the Co-Optimization of Fuels and Engines Initiative*. Pacific Northwest National Laboratory (PNNL), Richland, WA (United States).

Habibi, I. (2023). Penerapan Critical Path Method pada penyelesaian proyek rehabilitasi Jalan Parigi Lama di Kabupaten Sumedang. *Go-Integratif: Jurnal Teknik Sistem dan Industri*, *4*(1), 1–10.

Hasan, M. (2024). Mitigating project schedule risks by identifying subcritical paths and variance-critical activities. *Journal of Construction Engineering and Management*, *150*(8). https://doi.org/10.1061/JCEMD4.COENG-14821

Husna, R. A. A. (2022). Implementasi CPM dan PERT dalam memprediksi durasi serta biaya pembangunan Musala Al-Ikhlas di Kotawaringin Barat. *Focus ACTion of Research Mathematic*, *5*(1), 97–109. https://doi.org/10.30762/f_m.v5i1.633

Institute, P. M. (2019). *Practice standard for scheduling*. Project Management Institute.

Institute, P. M. (2021). *A guide to the Project Management Body of Knowledge (PMBOK guide) and the standard for project management*. Project Management Institute.

Jaber, H., Marle, F., Vidal, L.-A., & Didiez, L. (2018). Criticality and propagation analysis of impacts between project deliverables. *Research in Engineering Design*, *29*(1), 87–106.

Kammouh, O. (2022). Dynamic control for construction project scheduling on-the-run. *Automation in Construction*, *141*, 104450. https://doi.org/10.1016/j.autcon.2022.104450

Kim, K. (2020). Generalized resource-constrained critical path method to improve sustainability in construction project scheduling. *Sustainability*, *12*(21), 8918. https://doi.org/10.3390/su12218918

Kostrzewa-Demczuk, P. (2024). Construction schedule versus various constraints and risks. *Applied Sciences*, *14*(1), 196. https://doi.org/10.3390/app14010196

Lee, S., & Shvetsova, O. A. (2019). Optimization of the technology transfer process using Gantt charts and critical path analysis flow diagrams: Case study of the korean automobile industry. *Processes*, *7*(12), 917.

Marit, I. Y., Nursanti, E., & Vitasari, P. (2020). Critical path method to accelerate automotive maintenance duration. *International Journal of Scientific & Technology Research*, *9*(03), 6777–6782.

Pantis, I. T., Seica, A. V, & Blaga, F. S. (2024). Management of the relocation project of a production line using the critical path method. *Annals of the University of Oradea: Facsicle of Management & Technological Engineering*, *32*(2).

Saputra, N. (2021). Analisa penjadwalan proyek dengan metode Critical Path Method (CPM): Studi kasus pembangunan gedung rawat inap RSUD Abdul Manap Kota Jambi. *Jurnal Talenta Sipil*, *4*(1), 44–52. https://doi.org/10.33087/talentasipil.v4i1.48

Sholahuddin, M. (2024). Penerapan Critical Path Method (CPM) pada proyek rekonstruksi jalan untuk mengidentifikasi kegiatan pekerjaan jalur kritis. *DEARSIP: Journal of Architecture and Civil*, *4*(2), 72–84. https://doi.org/10.52166/dearsip.v4i02.7822

International Organization for Standardization. (2020). *ISO 21502:2020, Project, programme and portfolio management - Guidance on project management*. ISO.

Ulfa, S. (2021). Implementasi metode Critical Path Method pada proyek Synthesis Residence Kemang. *Jurnal Optimasi Teknik Industri*, *3*(1), 1–6. https://doi.org/10.30998/joti.v3i1.4167