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Evaluating Project Management Effectiveness in Rural Infrastructure: A Case Study of the Nayagram Piped Water Supply Scheme

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ABSTRACT

Water is required to sustain life, and safe and clean drinking water is a recognized universal human right. But for large portions of rural India, access to such a precious commodity is still an elusive dream. Government programs like the Jal Jeevan Mission are filling this gap by setting up major rural water supply schemes, one of which is the Nayagram Piped Water Supply Scheme for the Cachar district of Assam. The plan is to provide safe and drinkable water to the residents of the Nayagram village and its surrounding area by a sound-planned system of piped supply of water. Such projects can be successful only if they are supported by a range of factors such as planning, coordination, costing, scheduling, and punctual delivery. Delays, cost fluctuations, and resource mismanagement plague most public sector projects. For such situations, the successful management of the project is therefore essential.

The research will review the Nayagram Piped Water Supply Scheme through the tools and techniques of project management to study how effectively the project was functioning and to recommend remedial measures that can improve the effectiveness of comparable future projects.

Key words: Project Management, Piped Water Supply Scheme, Infrastructure Development, Public Utility Projects, Rural Water Supply

1. Introduction

Project Management is an organized methodology employed to initiate, plan, execute, control, and close teamwork to meet specific goals within predefined constraints of time, cost, quality, and scope. For the development of infrastructure, particularly public utilities such as water supply schemes, project management assures effective use of resources, timely delivery, and attainment of project goals without compromising sustainability and quality.

Over the last century or so, there has been an immense growth in the complexity of projects due to increased population needs, environmental factors, and limited budgets. The projects are now multiple- stakeholder affairs involving government entities, contractors, vendors, and beneficiaries, and thus, there needs to be systematic coordination and planning. Project management closes the gap between planning and implementation so that not only is a project completed, but done so efficiently.

The core domains of project management are:

1. Time Management: Time Management to ensure that the project is completed within the agreed time lines using tools such as Gantt Charts, Critical Path Method, or PERT (Program Evaluation and Review Technique) to identify critical tasks and potential delays.
2. Cost Control: Keeping track and controlling the budget to avoid overruns or unnecessary costs. Cost estimation and resource allocation are especially relevant here.
3. Scope Management: Determine what is and is not included in the project, to avoid " scope creep " a deliberate expansion of the scope of the project.
4. Quality management: Controlling the quality of the output throughout the project life cycle to ensure it is reliable, sustainable, and in accordance with its intended use.
5. Risk Management: Analysis, identification, and mitigation of potential risks that could affect the project.
6. Communication and stakeholder management: Stakeholders should be kept informed and engaged in order to obtain transparency, trust, and timely decision making.

All of these concepts become crucial in the context of the Nayagram Piped Water Supply Scheme. Drilling borewells, installing pipelines, building tanks, installing pumps, and testing are all part of a water supply project. The overall project schedule may be disrupted if one activity is disrupted or handled improperly. Therefore, using project management techniques like PERT and CPM allows for better workflow visualization, the identification of the most time-sensitive tasks, and resource reallocation to enable more seamless implementation.

Managers can take effective decisions to delay, reduce, and improve efficiency by employing strategies like crashing, which involves speeding up specific project activities at additional expense to shorten the project's overall duration, and float/slack calculation, which evaluates the extent of potential delays without compromising project completion.

Project management has an impact on public trust, resource use, and long-term community welfare in along with execution in public infrastructure projects like Nayagram. As a result, using an analytical, structured approach to project planning and monitoring is not only beneficial but also necessary for success.

1.1 Statement of the problem

Infrastructure projects in rural India, particularly water supply programs run by the government, often have problems. These problems include postponed completion, increased expenses, poor resource distribution, inadequate planning, along ineffective supervision. Although there are specific rules plus projected funds, several of those projects do not achieve what they set out to do.

Planned to deliver safe drinking water to people in the rural area of Cachar district, the Nayagram Piped Water Supply Scheme faced several difficulties during its execution. Without current supervision and project control methods that work, the possibility of wasted time and funds always remains.

The project requires assessment through the study of project management. The problem is determining if the plan adhered to a structured project management framework. If it didn't, we explore how standard tools like PERT, CPM, Gantt charts, along with project crashing methods could raise its performance.

The study's main question is

"How well was the Nayagram Piped Water Supply Scheme managed? How could project management tools benefit similar public infrastructure builds?".

1.2 Objective of the study

The study will evaluate how well project management tools work on a practical infrastructure build. Especially, the study aims to achieve the following objectives:

1 To study the structure, components, and timelines of the Nayagram Piped Water Supply Scheme.

2 To apply project management tools such as PERT, CPM, Gantt Charts, and Crashing to analyze the project timeline and dependencies.

3 To calculate float/slack, along with showing probable delay or waste areas.

1.3 Need of the study

1. Development of rural infrastructure, especially in the water supply segment, is of prime importance in the attainment of public health, poverty reduction, and sustainable development. Notwithstanding serious initiatives by the Government of India through programs like Jal Jeevan Mission (JJM), rural water supply schemes remain plagued by issues like project delays, cost escalations, inefficient resource usage, and inadequate monitoring systems. These inefficiencies usually result from the lack or inappropriate use of well-defined project management techniques in the planning and implementation stages.
2. The Cachar district of Assam's Nayagram Piped Water Supply Scheme was undertaken to remove the severe water shortages affecting a number of rural habitations. Yet success in such a project does not only rely on money or will—it needs to be planned, scheduled, coordinated, and executed with accuracy, all of which are within the realm of project management. With the significance of timely and effective delivery in public infrastructure projects, application of tools such as the Critical Path Method (CPM), Program Evaluation and Review Technique (PERT), Gantt charts, float analysis, and project crashing is imperative.
3. There is a discernible gap in scholarly literature and field documentation regarding the use of such project management methods in the context of rural, small-scale projects, especially in northeastern India. Such studies mostly engage with large urban infrastructure or industrial projects, and consequently, rural projects are underrepresented. Therefore, this research is required to fill that gap by assessing the Nayagram project from the perspective of project management, marking its successes and failures.
4. Through this analysis, the research hopes to emphasize the applicability and advantage of implementing a systematic project management process in rural development projects. It also hopes to make recommendations and insights that can be used in planning future public infrastructure projects so they are not only delivered within schedule and cost but also managed in a manner that ensures sustainability, people's ownership, and long-term usability.

1.4 Limitations of the study

The study faced several boundaries despite efforts to make it thorough.

1. The study is based entirely on secondary data from the Public Health Engineering Department (PHED), Silchar II Division. No primary data or field observations were conducted, which may affect the accuracy and completeness of the analysis..
2. Some project updates or internal records may not have been publicly available or up to date, which could affect the completeness of activity timelines or cost details.
3. The research focused on a single rural water supply project in Nayagram, limiting the generalizability of findings to other projects, especially larger-scale or urban infrastructure initiatives.
4. Due to a lack of access to budgetary data, the study could not conduct a detailed cost-benefit analysis or assess financial efficiency.
5. The crashing analysis was based on hypothetical cost/day assumptions rather than actual contractor or material costs, which may impact the precision of the recommendations.
6. Operational challenges, implementation bottlenecks, and long-term sustainability issues that might emerge after project commissioning were beyond the scope of this study.
7. Due to the scope of the secondary data, factors such as labor issues, weather disruptions, political influences, or administrative delays could not be deeply explored.

1.5 Research Methodology

The research methodology is a planned method a study uses to examine a problem. It says how data is gathered, studied, along explained to form sensible thoughts. This study's method is set up to consider how well project management methods work in the Nayagram Piped Water Supply Scheme. It uses known project management tools.

For this study, the method used is mostly description and analysis. It uses data from other sources. The structure will assess project planning, scheduling, as well as performance. It uses number-based techniques like PERT, CPM, float/slack analysis, and Gantt chart, showing next to crashing.

1.5.1 Research Project

The research follows a case study project, focusing on a single project—the Nayagram Piped Water Supply Scheme. A case study allows for a detailed, context-rich analysis of real-world implementation and outcomes. This project is suitable because it enables an in-depth exploration of how project management principles have been applied in a public infrastructure project and how these could be improved.

The current study is of exploratory in nature. Here, the project " Effective Project Management: A study on Nayagram Piped Water Supply Scheme" was studied and analyzed from the perspective of project management.

Qualitative, as it involves descriptive analysis of project phases, structure, and challenges.

Quantitative, as it applies project management techniques (PERT, CPM, crashing, float/slack calculations) to numerical project data like activity durations and sequencing

1.5.2 Data Collection Method

The study is based on secondary data, as primary fieldwork was not conducted due to time and access constraints.

Sources of Secondary Data Include:

1. The Verification Report of the Nayagram Piped Water Supply Scheme provided by the Public Health Engineering (PHE) Department, Silchar, Assam.
2. Government records, reports, and publications related to the Jal Jeevan Mission and the rural water force guidelines.
3. Academic journals, handbooks, and exploration papers on project management tools like PERT, CPM, and Gantt charts.

The data includes:

- List of project activities
- Estimated time durations (optimistic, pessimistic, most likely)
- Sequential dependency of activities

- Start and end times
- Information related to delays or time overruns (if any)

2.1 Review of Literature

2.1.1 Project Management

Author(s)	**Year**	**Focus Area**	**Key Findings**	**Relevance**
Zid, Kasim, & Soomro	2020	Iron Triangle & PM	Best practices improve cost, time, and quality; poor management causes delays, overspend, and low quality.	Recommends integrated PM practices for success.
Safapour et al.	2020	DOT Project Strategies	Team qualification and planning top PM success; survey of 96 DOTs.	Offers insights for transportation project managers.
Antipina & Velm	2021	Russian Construction PM	Emphasizes planning, coordination, and risk management amid infrastructure and economic challenges.	Suggests efficient PM models for construction in volatile economies.
Wolniak	2022	Industry 4.0 & PM	Structured PM boosts success in complex engineering contexts; traditional methods insufficient.	Highlights PM's role in high-tech industrial environments.
Shah, Bhatti, & Ahmed	2023	Sustainability in PM	Sustainability enhances construction outcomes; post-COVID challenges still exist.	Advocates green PM methods for sustainable construction.
Ibeanu, Nejad, & Ghasemi	2023	Urban Flood Management	Suggests integrated PM for flood disaster mitigation in Benin City.	Proposes strategic PM framework for disaster resilience.
Jaymin-Sanchaniya et al.	2024	Construction PM Practices	Risk and people management are critical; stakeholder mismanagement negatively impacts outcomes.	Recommends training in stakeholder and communication skills.
Misnan, Ismail, & Yan	2024	Sustainable PM	Cost, training, and change resistance hinder sustainability; solutions offer efficiency and innovation.	Reframes PM as key to sustainable development.
Adeloduna & Anyanwu	2025	Telehealth & PM	Agile/PMBOK enhances telehealth; PM improves accessibility and efficiency.	Bridges healthcare delivery and project management.

2.1.2 Project Planning and Scheduling

Author(s)	**Year**	**Focus Area**	**Key Findings**	**Relevance**
Yang, Yu, & Zhu	2020	Knowledge Integration via Planning	Strong planning improves knowledge integration and project success.	Validates planning’s strategic role in construction.
Bodunwa & Makinde	2020	CPM vs. PERT	CPM and PERT together improve schedule reliability.	Practical use of both methods in planning.
Pardha Saradhi et al.	2021	THFS & CPM	Fuzzy logic (THFS) adds realism to CPM under uncertainty.	Useful for planning in uncertain environments.
Nwadigo et al.	2021	Dynamic Scheduling	Proposes integrated simulation models (e.g., 4D BIM, DES).	Advocates hybrid models for dynamic planning.
Hatami et al.	2022	AI in Scheduling	Deep learning improves decision-making over conventional DES.	Shows potential of AI in modern scheduling.
Bachwani et al.	2023	CCPM in Mega Projects	CCPM better handles uncertainties than CPM/PERT.	Recommends CCPM for large-scale projects.

Author(s)	**Year**	**Focus Area**	**Key Findings**	**Relevance**
Ayele, Y. G.	2023	Planning's Project Impact	100% of respondents agreed strong planning leads to success.	Confirms planning as key success factor.
D. Suresh	2024	Scheduling in Services	Scheduling impacts project success via strategic tools like cloud systems.	Emphasizes scheduling in digital service industries.
Amarkhil & Elwakil	2023	EPS in Construction	EPS method reduced project duration by 40 days.	Introduces effective, structured scheduling framework.
Abogunrin et al.	2025	Healthcare Engagement	Structured scheduling improved healthcare worker engagement and delivery.	Shows planning's HR and service benefits.

2.1.3 Project Monitoring and Evaluation (M&E)

Author(s)	**Year**	**Focus Area**	**Key Findings**	**Relevance**
Kissi et al.	2019	M&E in Construction	M&E strongly linked to project scope and safety in Ghana.	M&E vital in developing construction sectors.
Gaibo et al.	2019	M&E in Kenya Counties	No significant M&E impact, but improvements are advised.	Highlights implementation gaps in M&E practices.
Macharia & Bowa	2020	NGO Education Projects	M&E staff competency and method relevance explain up to 26.7% variation in performance.	Advocates skill development and support for M&E.
Mgoba & Kabote	2020	PM&E in Water Projects	NGO projects more successful; calls for more community capacity building.	PM&E effective when community-involved.
Humera Amin	2024	Agency Theory & M&E	Monitoring fixes information asymmetry; both M&E resolve goal conflicts.	Separates strategic roles of monitoring and evaluation.

2.1.4 Piped Water Supply Schemes in India

Author(s)	**Year**	**Focus Area**	**Key Findings**	**Relevance**
Hooda & Damani	2019	JalTantra Design System	Web-based optimization system for rural piped water design.	Reduces manual errors and improves network efficiency.
Kumar, Bassi & Kumar	2022	Geological Context in Maharashtra	Surface-based schemes perform better than groundwater-based ones.	Emphasizes geology's role in rural water supply.
Ajay Kumar	2023	Water Quality & NRDWP	Quality remains an issue despite infrastructure growth.	Suggests more investment in quality infrastructure.
Kurian, Narasimhan & Narasimhan	2024	Inequity in Water Access	Inequity from uncontrolled withdrawal and topography; recommends scenario-specific fixes.	Advocates data-driven equity-based water planning.
Singh & Naik	2024	Jal Jeevan Mission (JJM) Impact	Tap connections reduce women's burden but inequities persist.	Suggests inclusive and targeted implementation strategies.
Mukherjee, Senapati & Ghosh	2025	Smart Tech in JJM	Smart meters, sensors, dashboards enhance efficiency, reduce waste, and ensure safety.	Highlights digital transformation in water governance.

2.2 Research gap

The existing body of literature on project management throws immense light on the application of tools like PERT, CPM, Gantt Charts, and Crashing techniques, particularly in large-scale urban infrastructural and industrial projects. Yet, there seems to be a visible lack of applications in rural piped water supply schemes. Particularly, there is less research on how such project management approaches are applied in areas such as Nayagram in Cachar, Silchar. Such studies mostly generalize results without addressing region-specific socio-economic as well as logistical issues that most often trap rural development projects.

Additionally, although several individual studies examine planning and scheduling separately, few studies exist that integrate analyses of timelines, budgets, and resource constraints simultaneously using tools such as PERT and CPM. The other key deficiency is the lack of emphasis on practical implementation issues, such as schedule variations, cost increases, and their reasons. These are very important for comprehending actual-world effectiveness of project management practices.

In addition, post-implementation reviews that assess project performance and suggest enhancements are rarely done, especially for public health engineering projects. This dissertation is an effort to fill these gaps through a holistic application of project management tools on the Nayagram Piped Water Supply Scheme and deriving insights into the successful implementation of projects, maintenance of scheduled timelines, and possible areas of enhancement in future similar projects.

3.1 Analysis and Interpretation of Objective 1:

Objective 1: To study the structure, components, and timelines of the Nayagram Piped Water Supply Scheme.

3.1.1 Project Structure Overview:

The project structure reflects a multi-tiered implementation model involving governmental oversight, private contracting, and community participation.

The Public Health Engineering Department (PHED), Silchar II Division, was the nodal agency responsible for planning, preparing the Detailed Project Report (DPR), tendering, quality control, supervision, and financial oversight.

The contractor M/s Lucky Enterprise was selected through a transparent bidding process to carry out construction, installation, and system commissioning.

Local governance was ensured through Formation of the Water User Committee (WUC) Nayagram (New Scheme) Water Supply & Sanitation Committee tasked with post-implementation operations and maintenance.

Appointment of Jal Mitras, namely Abujandal Barbhuiya and Mahibul Alam Barbhuiya, who served as liaisons for community awareness and quality monitoring.

This structure exemplifies a public-private-community partnership model for rural infrastructure execution, aligning with the JJM's sustainable and inclusive development objectives.

3.1.2 Project Components

The Nayagram Piped Water Supply Scheme features a multi-faceted infrastructure. It starts with Water Source Development, identifying sustainable groundwater or surface sources through quality tests and building infrastructure for non-invasive extraction. Water Treatment Infrastructure includes a Chlorination Unit for bacteriological safety and Sedimentation & Filtration units where needed, consistently meeting BIS quality standards.

The treated water is managed by a Storage and Distribution System, with an Overhead Storage Reservoir (OHSR) to handle demand and a network of PVC and GI pipelines optimized for hydraulic pressure and gravity flow. The scheme provides 105 Household Tap Connections (FHTCs), ensuring equitable access. Finally, Monitoring and Maintenance protocols, including regular water testing (33 samples) and community-led operations with trained Jal Mitras, ensure year round, quality-controlled, doorstep water supply.

3.1.3 Project Timeline:

The timeline of the project, from approval to handover, showcases systematic execution and milestone-based progress.

Milestone	**Timeline**
Approval by SLSSC	3rd SLSSC Meeting, FY 2020–2021
Start of physical work	Post-approval (exact date not provided)
Progressive fund release & inspections	2021–2022 onwards
System Testing and Commissioning	Early 2023

Project Completion and Handover	27th March 2023

Table 2: Nayagram piped water supply scheme project Timeline

The project was completed within a reasonable period of approximately two years post-approval, highlighting effective planning, fund management, and timely execution. The absence of major delays also suggests that project risks were managed efficiently.

Interpretation:

From the analysis, it is evident that the Nayagram Piped Water Supply Scheme was executed with precision and foresight. The project leveraged a decentralized and participative governance approach, while adhering to JJM technical and financial norms. The inclusion of marginalized households, community training, and operational sustainability mechanisms demonstrates best practices in rural infrastructure management.

3.1.3.1 The project components were well-aligned with BIS water quality standards and JJM norms.

3.1.3.2 Project structure enabled a balance of government oversight, private sector efficiency, and community ownership.

3.1.3.3 Timely completion underlines the strength of coordination among stakeholders and application of sound project management principles.

3.2 Analysis and Interpretation of Objective 2:

Objective 2: To apply project management tools such as PERT, CPM, Gantt Charts, and Crashing to analyze the project timeline and dependencies.

3.2.1 Activity List and Dependencies

The following table outlines the activities involved in the project, along with their immediate predecessors:

Sr. No.	**No.**	**Activity Name**	**Predecessor(s)**	**Duration**
A	A	Survey and Land acquisition	—	20
B	B1	Design and approval of estimates	A	10
	B2	Final work order	B1	2
C	C1	Procurement of materials	B2	10
	C2	Electricity connection Apply	B2	5
	C3	Ordering of pipeline and ESR material (staging + tank)	B2	3
	C4	Formation of the Water Users and Sanitation Committee	B2	7
D	D1	1. Construction of Underground Reservoir	C1	30
	D2	2. Construction of Sedimentation Tank	C1	25
	D3	3. Construction of Filtration Bed	C1	21
	D4	4. Construction of Pump House (Clear Water)	C1	8
	D5	5. Construction of ESR base (pile and pile cap)	C1	45
	D6	6. Construction of Pump House (Raw water)	C1	10
E	E1	Delivery of pipeline and ESR materials	D5, C3	30
	E2	Installation and charging of the transformer	C2	30
F	F1	Pipe Laying	E1	14
	F2	FHTC connection (Functional household tap connection)	F1	20
G	G	Installation of ESR (staging + tank installation)	E1	20
H	H1	Installation of pumps & commissioning	G, E2, D1, D2, D3, D4, D7	15
	H2	Internal Connection	G	14
I	I	Service Valve	H1, H2	5

J	J	Trial Run	I	3
K	K	Testing & Commissioning of ESR Tank, Pipeline	J, F2	15
L	L	Boundary Wall, Gate Installation and Site Development	K, D6	7
M	M	Handover to WUCs and PRI (Panchayati Raj Institution)	L, C4	7

Table 3: List of activities and their dependencies.

Notes on Logic:

1. C activities depend on final approvals (B2).
2. D activities depend on material procurement (C1).
3. E1 depends on both delivery order (C3) and construction of base (D5).
4. E2 logically follows the application (C2).
5. F1 and F2 are sequential.
6. ESR installation (G) follows delivery (E1).
7. Pump installation (H1) follows ESR (G), transformer (E2), pump houses (D4, D7) , Underground reservoir (D1), Sedimentation tank (D2) and Filtration bed (D3).
8. Final commissioning & handover follow testing (K) and physical infrastructure (L).

3.2.2 Critical Path Method (CPM)

CPM is a popular method of planning, scheduling, and controlling large and complex projects in project management. It is best applied in construction and infrastructure projects where numerous dependent activities have to be finished within a specified time and cost.

CPM assists in finding:

1. The longest chain of dependent activities (critical path).
2. Minimum duration of the project.
3. The tasks that are not going to impact the overall project schedule (float/slack).
4. Potential for resource levelling and optimizing the schedule.

In the Nayagram Piped Water Supply Scheme, the Critical Path Method (CPM) was utilized to break down the project into its individual activities, determine interdependencies, estimate their duration, and create a visual network. This helped determine the critical activities whose early completion is essential for the effective implementation of the scheme.

CPM Network Diagram:

A network diagram was constructed using the above activity breakdown. This diagram represents all project activities as nodes connected by arrows that indicate precedence relationships. The arrows denote the logical flow of work from start to finish.

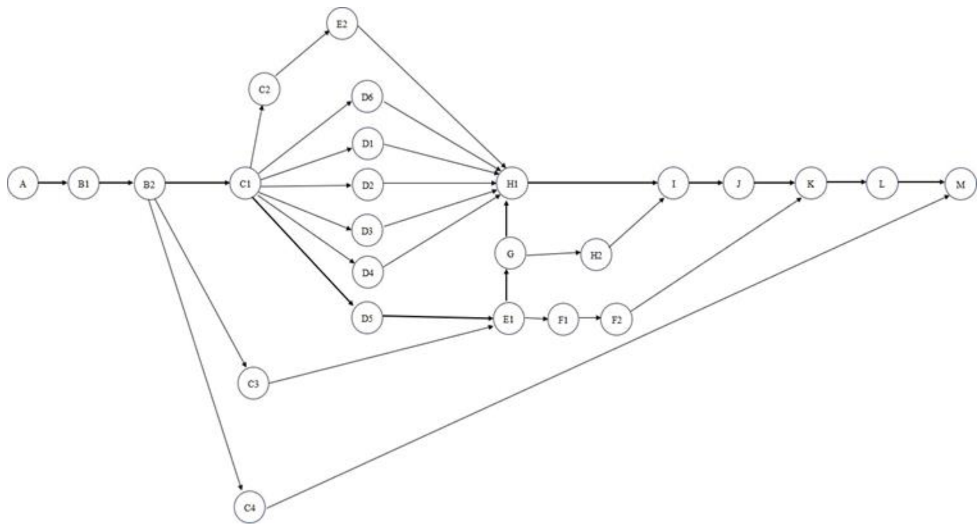

Figure 1: CPM Network Diagram of activities involved in the Nayagram Piped Water Supply Scheme

Path Analysis and Critical Path Identification:

To determine the critical path, all possible paths from the start node (Activity A) to the end node (Activity M) were enumerated, and the duration of each path was calculated.

S.No.	**Paths**	**Duration**
1	A → B1 → B2 → C1 → D5 → E1 → G → H1 → I → J → K → L → M	189
2	A → B1 → B2 → C1 → D5 → E1 → G → H2 → I → J → K → L → M	188
3	A → B1 → B2 → C1 → D5 → E1 → F1 → F2 → K → L → M	180
4	A → B1 → B2 → C3 → E1 → G → H1 → I → J → K → L → M	137
5	A → B1 → B2 → C3 → E1 → G → H2 → I → J → K → L → M	136
6	A → B1 → B2 → C3 → E1 → F1 → F2 → K → L → M	128
7	A → B1 → B2 → C1 → D1 → H1 → I → J → K → L → M	124
8	A → B1 → B2 → C1 → D2 → H1 → I → J → K → L → M	119
9	A → B1 → B2 → C2 → E2 → H1 → I → J → K → L → M	119
10	A → B1 → B2 → C1 → D3 → H1 → I → J → K → L → M	115

Table 4: Path Analysis and Critical Path Identification

The critical path is:

A → B1 → B2 → C1 → D5 → E1 → G → H1 → I → J → K → L → M

Total Project Duration: 189 days

Any delay in this path will directly delay the whole project. Other paths have slack/float and can afford limited delays without affecting completion.

Interpretation:

1. Total project duration is 189 days based on the critical path.
2. Critical path is: A → B1 → B2 → C1 → D5 → E1 → G → H1 → I → J → K → L → M.
3. Any delay in critical path activities will delay the entire project.
4. D5 (Construction of ESR base) and E1 (Material delivery) are long-duration and highly dependent tasks.
5. G (ESR installation) and H1 (Pump installation and commissioning) are key coordination points.
6. Activities like D1, D2, D3, C2, and F2 are not on the critical path and have float.
7. These non-critical paths can tolerate limited delays without affecting project completion.

8. Project monitoring should prioritize critical path tasks to avoid overruns.
9. Optimizing durations of D5, E1, or G can reduce total project time.
10. Critical path activities should receive focused resource allocation and risk mitigation.

3.2.3 PERT (Program Evaluation and Review Technique)

It is a project management technique used to manage uncertainty in estimating activity durations. Compared with the CPM, which relies on fixed estimates of time, PERT involves three time estimates: optimistic, most likely, and pessimistic, to derive a weighted average duration for each activity. This makes the planning of projects more realistic, particularly in big projects such as the Nayagram Piped Water Supply Scheme, where there are often delays because of logistics, weather conditions, or administrative sanctioning.

Purpose of using PERT in the Nayagram Scheme:

In the Nayagram Piped Water Supply Scheme, PERT was used to:

3.2.3.1 Estimate realistic activity durations.

3.2.3.2 Determine the expected project duration under uncertainty.

3.2.3.3 Identify probabilities of on-time completion.

3.2.3.4 Support risk management and contingency planning.

PERT Formula and Time Estimations:

Each activity's expected duration (Te) was calculated using the PERT formula:

$$Te = \frac{(O+4M+P)}{6}$$

Where:

O= Optimistic time (minimum duration assuming everything goes well)

M = Most likely time (realistic duration under normal conditions)

P = Pessimistic time (maximum duration if complications arise)

Additionally, the variance (σ²) and standard deviation (σ) of each activity were calculated to assess schedule uncertainty:

$$\sigma^2 = \left(\frac{P-O}{6}\right)^2$$

$$\sigma = \left(\frac{P-O}{6}\right)$$

PERT Analysis for Critical Activities

The following table presents PERT estimates and results for selected critical path activities:

Act	**Activity Name**	**O**	**M**	**P**	**TE = (O+4M+P)/6**	**SD = (P−O)/6**	**Variance**
A	Survey and Land acquisition	15	20	30	(15+80+30)/6 =**20.83**	2.5	6.25
B1	Design and approval of estimates	8	10	14	(8+40+14)/6 =**10.33**	1.0	1.00
B2	Final work order	1	2	3	(1+8+3)/6 = **2.00**	0.33	0.11
C1	Procurement of materials	8	10	15	(8+40+15)/6 =**10.50**	1.17	1.36
D5	ESR base (pile + pile cap)	40	45	55	(40+180+55)/6 =**45.83**	2.5	6.25

E1	Delivery of pipeline and ESR materials	25	30	40	(25+120+40)/6 =**30.83**	2.5	6.25
G	Installation of ESR (staging + tank)	15	20	25	(15+80+25)/6 =**20.00**	1.67	2.78
H1	Pumps installation & commissioning	12	15	20	(12+60+20)/6 =**15.33**	1.33	1.78
I	Service Valve	3	5	7	(3+20+7)/6 = **5.00**	0.67	0.44
J	Trial Run	2	3	5	(2+12+5)/6 = **3.17**	0.5	0.25
K	Testing & Commissioning	12	15	18	(12+60+18)/6 =**15.00**	1.0	1.00
L	Boundary Wall & Site Dev.	5	7	10	(5+28+10)/6 = **7.17**	0.83	0.69
M	Handover to PRI & WUCs	5	7	9	(5+28+9)/6 = **7.00**	0.67	0.44

Table 6: PERT Analysis for Critical Activities

Total Expected Duration (TE):

20.83 + 10.33 + 2.00 + 10.50 + 45.83 + 30.83 + 20.00 + 15.33 + 5.00 + 3.17 + 15.00 + 7.17 + 7.00 =

193.99 days ≈ 194 days

Total Standard Deviation (SD):

We first sum all the variances:

6.25 + 1.00 + 0.11 + 1.36 + 6.25 + 6.25 + 2.78 + 1.78 + 0.44 + 0.25 + 1.00 + 0.69 + 0.44 = 28.60

Then, Total SD $=\sqrt{28.60} \approx 5.34$ days

Probabilistic Analysis:

The Probabilistic Analysis in project planning offers information about the possibility of finishing the project within a given period. The method is very appropriate in projects with uncertain activity durations, as it takes into account variation and allows for improved planning and decision-making.

Expected Duration (Te) = 194 days

Standard Deviation (σ) = 5.34 days

These figures serve as the foundation for estimating completion probabilities using the normal distribution.

Probability of Project Completion

Based on the standard normal distribution (Z-distribution), we can approximate the probability of completing the project in a given number of days by using the following formula:

$$Z = \frac{X - \mu}{(\sigma)}$$

Where:

D = Target project duration

Te = Expected duration

σ = Standard deviation

Examples:

1. Probability of completing the project in 200 days:

$$Z = \frac{200-194}{5.34} = \frac{6}{5.34} \approx 1.12$$

From Z-table:

P(Z < 1.12) ≈ 0.8686 → 86.86%
There is approximately a 86.86% chance the project will finish within 200 days.

2. *Probability of completing the project in 210 days:*

$$Z = \frac{210-194}{5.34} = \frac{16}{5.34}$$

$$\approx 2.996$$

From Z-table:

P(Z < 2.996) ≈ 0.9986→ 99.86%

There is approximately a 99.86% probability that the project will be completed within 210 days.

3. There is almost a 100% chance the project will finish within 220 days.

$$Z = \frac{210-194}{5.34} = \frac{16}{5.34}$$

$$\approx 2.996$$

From Z-table:

P(Z < 4.87) ≈~1.0000→ 100%

There is almost a 100% chance the project will finish within 220 days.

Interpretation of PERT and Probabilistic Analysis:

1. PERT was used in the Nayagram Piped Water Supply Scheme to manage uncertainty by considering optimistic, most likely, and pessimistic durations, resulting in a realistic project schedule.
2. The expected duration of the entire project, based on PERT, is approximately 194 days.
3. The standard deviation of 5.34 days indicates a moderate level of uncertainty in the project schedule, which is typical for large-scale civil works.
4. Probability of Completion:
    a) 200 days: 86.86% chance of completion, with some risk of delay.
    b) 210 days: 99.86% chance, very high confidence of on-time completion.
    c) 220 days: Nearly 100%, considered a safe upper limit.
5. PERT provides visibility into schedule risks, enabling planners to identify buffer durations and prepare contingency plans.
6. By estimating the probability of on-time completion, the team can communicate more confidently with stakeholders.
7. With an 86.86% probability of completion within 200 days, this duration can be proposed as a realistic baseline for internal planning. For contractual or public commitments, 210 days provides a near-certain delivery buffer.

3.3 Analysis and Interpretation of Objective 3

Objective 3: *To calculate float/slack along with show probable delay or waste areas.*

3.3.1 Float/Slack Analysis

Float (also referred to as slack) in project management is the duration by which an activity can be postponed without pushing back the overall completion of the project. The study of float assists in determining which activities are flexible and which are fixed (i.e., on the critical path).

Types of Float:

3.3.1.1 Total Float: The largest lag permissible in an activity without delaying the entire project completion.

3.3.1.2 Free Float: The largest lag in an activity without delaying the early beginning of the next activity.

Float Calculation Methodology:

Float is computed with the formula:

Total Float (TF) = Latest Start (LS) – Earliest Start (ES) or

TF = Latest Finish (LF) – Earliest Finish (EF)

Where:

ES/EF are calculated with a forward pass through the network. LS/LF are obtained with a backward pass.

Critical path activities possesses zero float, i.e., cannot be postponed

Activity	Activity Name	Duration (days)	EST	LST	Total Float
A	Survey and Land acquisition	20	0	0	0
B1	Design and approval of estimates	10	20	20	0
B2	Final work order	2	30	30	0
C1	Procurement of materials	10	32	32	0
C2	Electricity connection Apply	5	22	30	8
C3	Ordering of pipeline and ESR material	3	22	24	2
C4	Formation of WUSC	7	22	30	8
D1	Construction of UG Reservoir	30	32	40	8
D2	Construction of Sedimentation Tank	25	32	35	3
D3	Construction of Filtration Bed	21	32	35	3
D4	Construction of Pump House (Clear Water)	8	32	35	3
D5	ESR base (pile + pile cap)	45	32	32	0
D6	Construction of Pump House (Raw Water)	10	32	45	13
E1	Delivery of pipeline and ESR materials	30	77	77	0
E2	Transformer installation and charging	30	27	35	8
F1	Pipe Laying	14	61	65	4
F2	FHTC Connection	20	75	85	10
G	Installation of ESR	20	107	107	0
H1	Pumps installation & commissioning	15	127	127	0
H2	Internal Connection	14	81	85	4
I	Service Valve	5	142	142	0
J	Trial Run	3	147	147	0
K	Testing & Commissioning	15	150	150	0
L	Boundary Wall & Site Dev.	7	165	165	0

M	Handover to PRI & WUCs	7	172	172	0

Table 8: Float Analysis of All Activities (Critical & Non-Critical)

Interpretation of Float Analysis

1. Certain activities are designated as critical activities due to having zero float. These include activities like A, B1, B2, C1, D5, E1, G, H1, I, J, K, L, and M. Their zero float signifies that they are on the critical path, meaning any delay in these tasks will directly impact the overall project completion timeline. Therefore, close monitoring of these activities is essential to prevent schedule overruns.
2. In contrast, non-critical activities possess a positive float, offering a degree of scheduling flexibility. Examples of such activities are C2, C3, C4, D1, D2, D3, D4, D6, E2, F1, F2, and H2. This positive float indicates that these tasks can experience some delay without affecting the project's overall deadline. For instance, D6 (Construction of Pump House - Raw Water) has the project's highest float at 13 days, allowing it to start 13 days later without impacting the project' timeline. These floats serve as valuable buffer periods, capable of absorbing minor unforeseen delays.
3. The presence of float significantly enhances project flexibility and resource planning. Project managers can leverage this flexibility to optimize resource allocation, particularly for non-critical tasks. Furthermore, float aids in prioritizing work; critical tasks demand uninterrupted focus, while non-critical tasks can be adjusted as needed.
4. Additionally, non-critical activities with float function as a risk buffer. They can absorb unexpected issues that may arise elsewhere in the project. However, it's crucial to continuously track these floats, as they can diminish if upstream activities experience delays.

3.3.2 Delay & Waste Area Identification

Understanding where delays and inefficiencies can arise is crucial for improving future project outcomes. In the Nayagram project, a detailed analysis of timelines and float reveals potential delay- prone and waste-generating areas.

A. *Delay-Prone Areas*

1. Activities such as Survey & Land Acquisition (A), ESR Construction (D5), Pipeline & ESR Material Delivery (E1), and Pump Installation & Commissioning (H1) are all zero float. These are high-risk areas for delay, as any slippage directly affects the entire project timeline. Root causes may include Land clearance issues, Design approval bottlenecks, Material delivery delays, and Contractor unavailability or inefficiency
2. Delays in procurement (e.g., pipes, tanks, pump sets) due to vendor lead times, payment delays, or logistics bottlenecks can cascade into downstream construction delays.
3. Activities like H1 (Pump Installation) depend on multiple predecessors (e.g., D1 to D4), increasing the chances of interruption or coordination failures.

B. *Waste Areas / Inefficiencies*

1. Activities with substantial float, such as D6 (Pump House - Raw Water) and H2 (Internal Connection), present a potential for inefficiency if not managed effectively. Without proper oversight, these tasks can lead to underutilized resources and idle manpower. Furthermore, a lack of proactive management for these activities might result in delays when mobilizing teams to critical areas, thereby impacting the overall project flow.
2. Opportunities exist to optimize the execution of parallel tasks, particularly those with uneven durations. For instance, FHTC connections (F2) could be run in parallel with more float-flexible tasks to potentially reduce the overall project duration. Additionally, any wasted days between tasks that have no dependencies could be minimized through techniques like crashing or more efficient scheduling.
3. Administrative processes, such as Design Approval (B1) and Final Work Order (B2), are often bureaucratic and can become significant bottlenecks if not adequately pre-planned or streamlined. Proactive engagement and optimization of these processes are crucial to prevent them from causing unforeseen delays in the project timeline.

4 Findings of the Study

4.1 Findings from Objective 1

1. The Nayagram Piped Water Supply Scheme reflects a well-structured and meticulously planned rural infrastructure initiative aimed at ensuring the delivery of safe and potable water to underserved communities in Latigram and surrounding habitations. The scheme was designed per the core principles and technical standards of the Jal Jeevan Mission, with its structure encompassing all major elements

essential for sustainable water supply delivery, including source development, water treatment, overhead storage, and an extensive distribution network. The project layout effectively integrated strategic engineering elements such as optimal location of storage tanks, efficient piping systems based on local topography, and mechanisms for maintaining hydraulic pressure. These components were developed keeping in mind the region's geomorphological challenges, seasonal variations, and population distribution.

2. The primary water source was selected based on rigorous water quality testing, ensuring a safe and sustainable yield throughout the year. Essential treatment units, such as chlorination systems and basic filtration setups, were integrated into the project to meet BIS standards for drinking water. The treated water is stored in Overhead Storage Reservoirs (OHSRs) and distributed to 105 individual households via a carefully planned piped network. The scheme's household-level tap connections (FHTCs) emphasize the mission’s goal of “Har Ghar Jal,” delivering clean water directly to the premises of rural households.
3. In terms of implementation timeline, the project was approved during the 3rd SLSSC meeting for 2020–21 and was completed and handed over on March 27, 2023. The timeline indicates a clear progression from planning, DPR preparation, contractor selection, to physical execution and commissioning — all completed within a reasonable and structured timeframe. The involvement of various stakeholders, including the PHED, Silchar II Division, the executing contractor M/s Lucky Enterprise, and the local community ensured smooth coordination and adherence to deadlines. Financial disbursements were aligned with project milestones, and robust monitoring mechanisms were in place to track progress and ensure compliance.
4. Overall, the Nayagram Piped Water Supply Scheme stands out as a model rural infrastructure project with a clearly defined structure, logically sequenced components, and a well-managed timeline. It serves as an exemplary case of how integrated project planning and participatory governance can translate into sustainable service delivery and improved rural living standards.

4.2 Findings from Objective 2

1. The Critical Path Method (CPM) analysis reveals that the Nayagram Piped Water Supply Scheme has a project duration of 189 days based on deterministic scheduling. The critical path comprising activities A → B1 → B2 → C1 → D5 → E1 → G → H1 → I → J → K → L → M indicates the sequence of tasks that directly influence the project’s completion date. Any delay along this path will cause a direct delay in the entire project. Notably, tasks such as D5 (the longest task), E1 (linked to material delivery), and G and H1 (installation-related tasks) require particular attention to avoid potential project delays. In contrast, non-critical activities such as D1, D2, and F2 have float or slack, offering some scheduling flexibility and acting as buffers for managing minor disruptions.
2. The Gantt Chart serves as a comprehensive visual timeline that outlines the sequencing and duration of all project tasks. It confirms that critical path activities do not overlap, reflecting the strict dependencies between them. This chart is instrumental for tracking project progress, allocating resources efficiently, and setting key milestones. It also supports continuity by helping stakeholders monitor task initiation and completion dates. This is particularly valuable in infrastructure projects where coordination among multiple departments and contractors is essential.
3. The Program Evaluation and Review Technique (PERT) complements the CPM by introducing probabilistic analysis into the planning process. The expected project duration using PERT is approximately 194 days, which accounts for potential uncertainties and risks. The calculated standard deviation of 5.34 days suggests a moderate level of risk. According to the PERT analysis, there is an 86.86% chance the project will be completed within 200 days, a 99.86% chance within 210 days, and near certainty of completion within 220 days. These insights are crucial for contingency planning and provide a more realistic picture of potential delays due to weather, logistical issues, or bureaucratic hurdles.
4. In conclusion, the integration of CPM, Gantt Chart, and PERT in managing the Nayagram Piped Water Supply Scheme provides a robust framework for project management. CPM offers a clear roadmap for prioritizing tasks and identifying bottlenecks, while the Gantt Chart enhances planning through visual clarity and timeline tracking. PERT adds a layer of risk analysis, helping planners prepare for uncertainties and build appropriate buffers. Together, these tools enable better resource allocation, more informed decision-making, and greater confidence in achieving timely and successful project delivery, particularly in the context of complex public infrastructure projects.

4.3 Findings from Objective 3

1. Based on the float and slack analysis, as well as the identification of delay-prone and inefficient segments within the Nayagram Piped Water Supply Scheme project, several key observations have emerged. A total of 13 activities were identified with zero float, placing them on the critical path. These activities include essential components such as Survey and Land Acquisition, Design Approval, ESR Base Construction, Material Delivery, and Pump Installation. Since these tasks have no scheduling flexibility, any delay in their execution would lead directly to a delay in the overall project timeline. This highlights the need for strict oversight, timely approvals, and proactive execution on the critical path.
2. In contrast, several non-critical activities exhibit positive float values, offering limited scheduling flexibility. Tasks like the Construction of the Raw Water Pump House, Internal Plumbing Connections, and FHTC Connections have float ranging from 2 to 13 days. The highest

float was noted in the Raw Water Pump House construction activity, presenting a potential window for redistributing resources or managing time buffers more effectively. This float provides a degree of flexibility that can be strategically utilized to support critical path tasks and improve overall resource efficiency.

3. The analysis suggests that float can be a valuable tool in optimizing resource allocation. Activities with higher float can tolerate minor delays without affecting the overall project completion date, allowing manpower, machinery, or materials to be shifted temporarily to areas with tighter deadlines. However, such flexibility must be managed carefully to avoid creating inefficiencies or unnecessary idle time.
4. Delays were found to be more likely in tasks involving external dependencies, such as land acquisition, regulatory approvals, and procurement processes. These administrative and supply- chain-related activities are particularly vulnerable to bureaucratic slowdowns and vendor lead time variability. As such, they represent high-risk areas despite not always being on the critical path. This necessitates careful coordination with government departments and vendors to mitigate potential schedule disruptions.
5. Another significant finding relates to the potential for resource wastage in activities with high float. If not actively scheduled and monitored, these tasks may lead to underutilization of available labor and equipment, adding to overall project costs. The Raw Water Pump House and Internal Plumbing Connections are examples where resource planning must be refined to ensure that float does not translate into inefficiency.
6. The analysis also revealed that tasks depending on multiple predecessors, such as Pump Installation and Commissioning, are particularly vulnerable to delays due to poor coordination in the dependency chain. Any misalignment in upstream tasks can create a domino effect, cascading delays into subsequent activities. This interdependency requires precise sequencing and communication among teams to ensure smooth workflow transitions.
7. Opportunities for schedule optimization were identified through the rescheduling or overlapping of non-critical tasks. For instance, FHTC Connections, which currently carry float, could be advanced or run concurrently with other activities to compress the overall project duration. Such adjustments, if managed well, can enhance project efficiency without compromising the quality of work.
8. Finally, although several tasks currently have positive float, these buffers are dynamic and can be reduced or eliminated if delays occur in predecessor activities. Therefore, float must be actively monitored and reassessed throughout the implementation phase. This ongoing evaluation is essential for effective schedule control, risk management, and maintaining confidence in on-time project delivery.

5. Conclusion

Nayagram Piped Water Supply Scheme, like most rural development projects throughout India, is plagued by several limitations that render it ineffective. They include deficiencies in needed resources, difficult terrain that complicates implementation, and administrative delays due to bureaucratic dawdling. Nonetheless, studies in this field have convincingly shown that the prudent and ethical use of project management tools can result in significant enhancements. Notably, the tools can significantly enhance the accuracy of planning exercises, maximize the effectiveness of available resources, and achieve timely project completion.

By adding to traditional field experience, including the practical expertise acquired through work site experience, with advanced analytical scheduling methods, project managers can transform otherwise routine public works into projects that are not only strategically managed but also performance-based in focus. The Nayagram lessons are not only relevant and useful to planners and engineers directly engaged in the design and implementation of such projects, but also to policymakers and administrators looking for effective and efficient ways of providing public services to citizens.

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