Analyzing Causes and Effects of Delay in Pipe Distribution network (PDN). – A Case Study of Mhaishal Lift Irrigation Maharashtra, India

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Abstract - ***Maharashtra, a state with significant agricultural output, faces severe challenges due to its vulnerability to drought. In Western Maharashtra, several districts are particularly vulnerable to drought includes Pune, Satara, Sangali, Solapur and Ahmadnagar districts. Several water supply schemes and initiatives have been implemented in Maharashtra to address water scarcity, particularly in drought-prone areas. Krishna-Koyna Lift Irrigation Scheme plays vital role in solving these water scarcity issue. Water from Krishna River at Mhaishal KT weir (A/p- Mhaishal, Tal- Miraj, Dist-Sangali) lifted to irrigate 81697 Ha area in Sangali & Solapur district. Water lifted from krishna river at mhaishal KT Weir is distributed through system of Canal Distribution Network (CDN) & Pipe Distribution Network (PDN). The conventional Canal distribution systems, are less expensive and easier to maintain than Pipe Distribution System, but have some drawbacks. To overcome this drawback and meet the demands of modern irrigation there is need of Pipe distribution system for water supply. The main aim of this project is to find the causes and effects of delay in Pipe Distribution Network System (on the basis case study on of Mhaishal LIS scheme, Maharashtra, India) and suggestion of remedial measures for these factors contributing to delay. This study is not only crucial for the PDN system of Mhaishal LIS, but it also has significant implications for equivalent irrigation projects internationally.***

Key Words*: *Pipe Distribution Network (PDN), Canal Distribution Network (CDN). **Contractor, Manufacture Relative Importance Index (RII), Earn Value Management (EVM), Time Overrun, Cost Overrun**

I.INTRODUCTION

The Water Supply Scheme ensures the collection, treatment, storage, and distribution of water to meet the needs of domestic, industrial, and agricultural sectors. It sources water from rivers, lakes, and groundwater, followed by purification in treatment plants before distributing it through pipelines. Proper planning, forecasting, and infrastructure are essential to ensure water availability, maintain quality standards, and build resilience against challenges like droughts, floods, and contamination.

The Water Resource Department is responsible for the planning, development, and sustainable management of water resources. It conducts water assessments, promotes conservation methods like rainwater harvesting, and manages surface and groundwater use. The department also handles disaster response during droughts or floods, regulates water rights, and works with local bodies to ensure equitable water distribution while protecting natural ecosystems.

With increasing pressure from climate change, urbanization, and pollution, the department's role is more vital than ever. It focuses on climate-resilient strategies such as desalination, water recycling, and efficient irrigation. Combatting pollution through regulations, water quality monitoring, and public awareness is also key. Together, the Water Supply Scheme and the Water Resource Department aim to ensure a clean, safe, and sustainable water future for all.

II.METHOD OF IRRIGATION

Major irrigation projects are developed to provide a reliable water supply for agriculture, industries, and communities, especially in areas where natural sources are inadequate. These projects incorporate various irrigation methods tailored to regional needs, terrain, water availability, and crop types. Traditional methods like flood, furrow, and basin irrigation are commonly used in flat or flood-prone areas, though they vary in efficiency and water use. Basin and furrow methods are slightly more efficient than flood irrigation and better suited to specific crop needs and soil conditions. Advanced methods like drip, sprinkler, and subsurface irrigation offer greater water efficiency and are increasingly adopted in water-scarce regions. Drip irrigation delivers water directly to the root zone, minimizing evaporation and runoff, while sprinkler systems mimic rainfall and are suitable for uneven terrains and various crop types. Subsurface irrigation systems,
especially subsurface drip irrigation, offer precise watering below the soil surface, promoting root development and minimizing weed growth. These methods support higher crop yields and are ideal for high-value or sensitive crops like fruits, vegetables, and greenhouse plants.

In addition to direct irrigation systems, supporting methods like rainwater harvesting, canal irrigation, lift irrigation, and the use of check dams and reservoirs enhance water availability. Rainwater harvesting stores seasonal rainfall for later use, while canal systems transport water from distant sources to farmlands. Lift irrigation helps supply water to elevated areas using pumps, and check dams ensure year-round irrigation by storing excess rainwater. By selecting appropriate techniques, major irrigation projects can maximize water use efficiency, support sustainable agriculture, and boost food security and rural development.

III.MHAISHAL LIFT IRRIGATION SCHEME

The Mhaisal Lift Irrigation Scheme (MLIS) is a significant irrigation project located in the Sangli district of Maharashtra, designed to combat water scarcity in the region and improve agricultural productivity. Here's a more detailed look at the scheme:

3.1 Overview of the Mhaisal Lift Irrigation Scheme (MLIS):

1. Location: Mhaisal, in the Sangli district, Maharashtra.

2. Objective: The primary goal of the Mhaisal Lift Irrigation Scheme is to provide a reliable irrigation source to the drought-prone regions of the Sangli and Solapur districts. These areas often face water scarcity due to irregular monsoon rains, and MLIS aims to ensure year-round irrigation for agricultural land.

3. Water Source: The scheme draws water from the Krishna River, which is one of the major rivers in western India.

3.2 Key Features of the Scheme:

1. Lift Mechanism: The scheme uses a lift irrigation method to raise water from the Krishna River to the fields. It involves lifting the water in phases to irrigate areas located at varying elevations.

2. Irrigation Coverage: The total area that will be irrigated under the Mhaisal Lift Irrigation Scheme is approximately 81,000 hectares of agricultural land. This large-scale irrigation coverage is expected to benefit thousands of farmers in the region.

3. Water Lifting Capacity: The project uses a series of pumps and canals to lift and channel water across various distances. The water is pumped up to 600 meters in elevation to reach the agricultural fields.

4. Energy Demand: The MLIS requires significant energy to pump water over long distances and lift it to such high elevations. At its peak, the scheme uses about 90 megawatts (MW) of power annually.

Mhaishal Lift Irrigation Scheme is designed to provide irrigation facilities to drought-prone regions in Sangli & Solapur Districts by lifting water from the Krishna River and distributing it to the surrounding areas. Here are some key details about the scheme:

Table no 3.1: Salient Features

Sr. no	Attribute	Particulars
1.	Project name	Mhaishal Lift Irrigation, Project
2.	Purpose of Project	To lift water from Mhaishal KT weir on Krishna River to irrigate drought-prone Areas in Sangli & Solapur District.
3.	Cultivable Command Area (CCA)	128112 Hectors
4.	Irrigation Potential	81697 Hectors

Mhaishal KT weir, constructed on Krishna River at Mhaishal, Tal- Miraj, Dist-Sangali. The Mhaisal Lift Irrigation Scheme (LIS) is an ambitious infrastructure project aimed at providing irrigation water to drought-prone areas in Sangali & Solapur districts. Water from Krishna River at Mhaishal KT weir lifted to irrigate 81697 Ha area in Miraj, Kavathemhankal, Jath, Tasgaon tahsils of Sangali district and Sangola, Mangalvedha tahsils of Solapur district. Water lifted from krishna river at mhaishal kt weir is distribute through system of CDN and PDN

IV. OBJECTIVE

This project is undertaken to analyses the causes & effects of delays in PDN - A case study of Mhaishal Lift Irrigation scheme, Maharashtra, India.

1. To study the present status and make literature review of ongoing PDN system.
2. To identify factors contributing to delays and assess their impacts on selected ongoing project.
3. To prepare questionaries' survey obtained through contractor, site engineer, labour etc.
4. To carry out Analysis of various responses obtained for selected PDN water supply project.
5. To recommend best suggestive measures for minimizing causes of delays & improving productivity

V.METHODOLOGY

Following methodologies are adopted for –

1. Collection of preliminary information about PDN water supply system through literature review.
2. Assessing the current situation of Mhaishal lift irrigation scheme.
3. Selection of ongoing PDN project of water supply scheme for study.
4. Gathering necessary data by conducting-
   - Questionnaires survey
   - Site visit
   - Checklist
5. Analysis of collected data-
   - Finding causes of delay.
   - Effects of delay.
6. Conduction of awareness program on site in order to improve productivity of work.
7. Suggestion of remedial measures to avoid causes of delay
8. Results and Conclusions.

VI.QUESTIONARIES' SURVEY AND DATA COLLECTION

This chapter focuses on the methodology adopted to analyse the causes and impacts of delays in Pipeline Distribution Network (PDN) projects, particularly in irrigation systems. Building upon the literature review and execution methods discussed previously, a detailed project planning and data collection process was carried out. A structured survey form was distributed across various project sites to gather stakeholder feedback on factors contributing to project delays. The objective was to identify critical delay factors by engaging respondents like engineers, contractors, and farmers, and to explain the project purpose and guidelines during the survey process.

6.1 Analytical Approach and Key Factors:

The methodology involves a systematic blend of literature review and field data analysis. Key delay factors were first identified through previous studies and then validated through stakeholder surveys. The responses were analysed using the Relative Importance Index (RII) method, enabling prioritization based on the perceived impact of each factor. The study classified delays into three major categories: those related to the Owner/Department/Water Resource Department (WRD), Contractors and Subcontractors, and Manufacturers and Suppliers. This structured approach offers a data-driven foundation to understand and address delays in PDN projects effectively.

6.2 Stakeholder Involvement and Structured Evaluation:

The analysis emphasizes the involvement of multiple stakeholders whose roles directly influence the timely execution of PDN projects. Delays can stem from administrative inefficiencies, poor contractor performance, or supply chain disruptions. By categorizing the causes into distinct groups—Owner/WRD-related, Contractor/Subcontractor-related, and Manufacturer/Supplier-related—the study ensures a focused evaluation of each contributor. This structured methodology not only aids in pinpointing the most critical delay factors but also supports the development of targeted solutions to enhance project efficiency and minimize future disruptions.

The questionnaire survey is a key tool for gathering comprehensive insights from various stakeholders involved in Pipeline Distribution Network (PDN) irrigation projects. It captures data from farmers, project staff, local leaders, and technical personnel to identify the causes and impacts of project delays. By addressing areas such as resource availability, administrative inefficiencies, technical issues, and weather-related challenges, the survey provides both quantitative and qualitative information. This dual approach helps uncover not just the extent of the delays—such as duration and frequency—but also the underlying reasons and their effects on water distribution and agricultural productivity.

Moreover, the survey promotes stakeholder participation and transparency by involving those directly affected by the delays. Encouraging open and honest responses fosters accountability and strengthens collaboration among PDN teams and local communities. The insights gained enable evidence-based decision-making and support the development of targeted strategies to reduce delays. Ultimately, the survey data helps PDN optimize planning, allocate resources effectively, and improve project execution, contributing to better irrigation outcomes and enhanced livelihoods for the farming communities

VII. METHOD FOR ANALYSIS

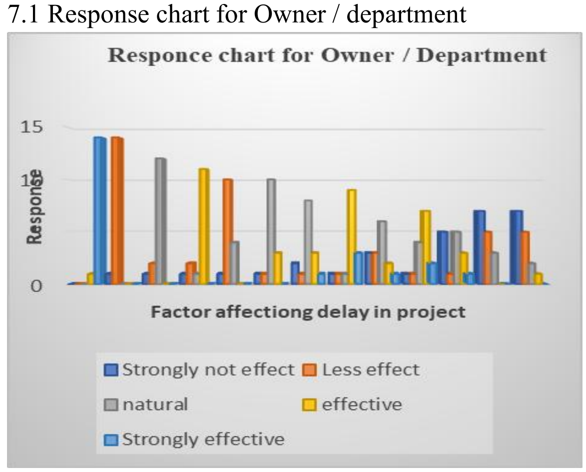
To assess on-site productivity and identify project inefficiencies, several statistical methods such as Work Sampling, Field Surveys, Delay Models, and Simulation Analysis are used. Among them, the Relative Importance Index (RII) is a widely applied technique for ranking factors based on stakeholder feedback.

RII uses a five-point Likert scale to quantify the perceived impact of various factors influencing delays or productivity. Respondents rate each factor from "Strongly Not Effective" to "Strongly Effective." The RII is then calculated using a formula that weights each response level, producing a percentage score (0–100%). Higher scores indicate greater significance. This method helps in prioritizing key issues, supporting evidence-based decision-making for improved planning and RERA-compliant project execution.

The use of RII in PDN (Pipeline Distribution Network) projects is especially valuable as it translates subjective stakeholder perceptions into measurable data, enabling project managers to focus on the most critical delay factors. By ranking issues such as administrative delays, resource shortages, or contractor inefficiencies, RII supports targeted action and efficient resource allocation. This structured analysis not only improves project planning and monitoring but also enhances transparency and accountability among all parties involved, ultimately contributing to timely project completion and better overall performance.

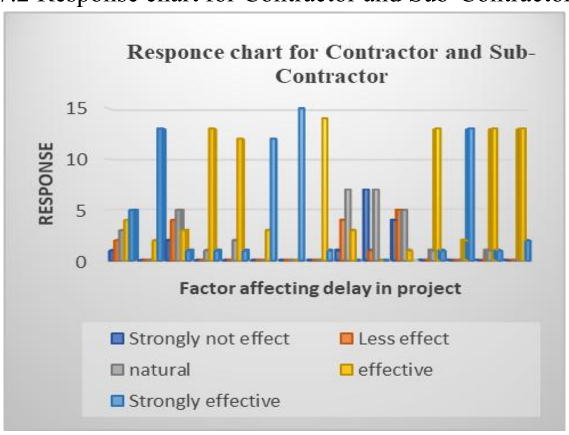
The RII method is simple to apply and interpret, making it accessible for both technical and non-technical stakeholders involved in PDN projects. Its adaptability allows it to be used at various project stages—planning, execution, and review—ensuring continuous improvement. By consistently identifying and addressing high-impact factors, organizations can minimize delays, enhance productivity, and ensure more reliable water distribution systems, which are essential for supporting agricultural and community needs.

7.1 Response chart for Owner / department



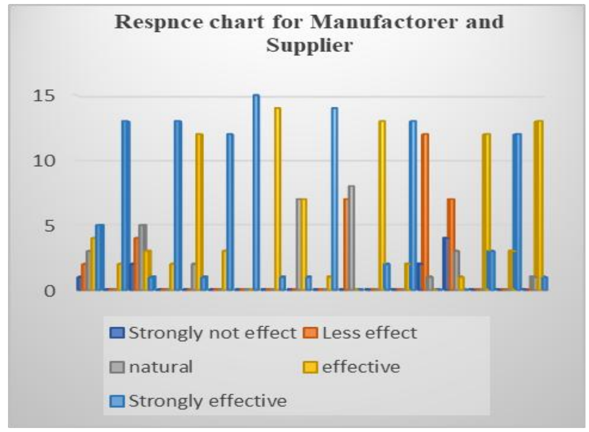
The graph titled "response chart for owner / department" illustrates stakeholder feedback on various factors affecting delays in pipeline distribution network (PDN) projects. It categorizes responses into five levels: *strongly not effective, less effective, natural, effective, and strongly effective.* The most significant factors, receiving the highest number of "strongly effective" responses (14 each), are delayed payments and frequent design changes, indicating these are perceived as the most impactful delay causes. Other highly rated delay factors include inefficient decision-making, poor project planning, and delay in site handover, each showing a strong leaning toward "effective" and "strongly effective" ratings. In contrast, factors like political changes, natural disasters, and design errors received more balanced or lower ratings, suggesting moderate impact. Overall, the chart highlights financial and planning issues as the most critical owner-related contributors to project delays

7.2 Response chart for Contractor and Sub-Contractor



The chart titled "Response Chart for Contractor and Sub-Contractor" presents stakeholder feedback on factors contributing to delays in PDN projects related to contractor and subcontractor performance. The highest-rated factors marked as *"Strongly Effective"* causes of delay include Local Public and Political Issues (15 responses), Subcontractor Delays, Cash Flow Issues, Late Delivery of Materials, and Supply Chain Disruptions, each receiving 13 or more strong agreement responses. Additionally, Poor Project Management, Equipment Failure or Shortage, and Inadequate Equipment or Tools are also perceived as major delay contributors. In contrast, factors like Poor Coordination with Main Contractor, Delayed Mobilization, and Failure to Follow Safety Standards received more moderate ratings across categories. Overall, the chart highlights that political interference, resource shortages, and logistical inefficiencies are among the most critical contractor-related factors impacting timely project execution.

7.1 Response chart for Manufacturer and Supplier



The chart titled "Response Chart for Manufacturer and Supplier" displays stakeholder perceptions regarding various delay factors in PDN projects associated with manufacturers and suppliers. The most significant issues identified, with the highest "Strongly Effective" responses, include Late Delivery of Materials (15 responses), Supply Chain Disruptions, Lack of Certification or Documentation, Poor Packaging and Handling, and Failure to Follow Safety Standards—each receiving 13 or more top-tier ratings. Similarly, Cash Flow Issues, Equipment Failure or Shortage, and Strikes of Labour were also rated as major contributors to delays. In contrast, Quality Issues and Production Capacity showed more moderate ratings. Overall, the chart highlights that material delivery, documentation, and supply logistics are the most pressing manufacturer/supplier-related factors affecting timely project completion.

VIII. CASE STUDY FOR MHAISHAL PDN WORK –SAHYADRI CONSTRUCTION COMPANY

8.1 Earn value management (EVM)

The section outlines the application of Earned Value Management (EVM) as a performance measurement tool in pipeline irrigation projects. EVM integrates scope, schedule, and cost data to evaluate project progress and efficiency. Key components include Planned Value (PV), Earned Value (EV), and Actual Cost (AC), which help in calculating variances and performance indices. Metrics such as Schedule

Variance (SV) and Schedule Performance Index (SPI) determine whether a project is ahead or behind schedule, while Cost Variance (CV) and Cost Performance Index (CPI) assess budget adherence. These calculations enable project managers to take proactive measures for risk mitigation, cost control, and timeline management.

Using EVM, project data was collected from two sites—Salagare Branch Canal and Kalambi Branch Canal—managed by Sahyadri Construction Company. The analysis focused on identifying the impacts of time and cost overruns. Time overruns were linked to delays in land acquisition, poor weather, regulatory lags, and inefficiencies in contractor performance, which negatively affect crop cycles and stakeholder confidence. These delays, in turn, often led to cost overruns due to rising labor and material costs, scope adjustments, and project mismanagement. The data from both sites were tabulated and analyzed using EVM metrics, helping to pinpoint inefficiencies and support more accurate forecasting, budgeting, and corrective planning for future irrigation projects.

8.2 time over run

Time overrun in a pipeline irrigation project occurs when the construction and commissioning of the system exceed the planned schedule. This can result from delays in land acquisition, slow regulatory approvals, unforeseen site conditions, contractor inefficiencies, or extreme weather events like heavy rains or floods. Such delays disrupt the entire workflow—excavation, pipe laying, testing, and commissioning—all get pushed back, impacting agricultural cycles. As a result, farmers may not receive water on time, leading to reduced crop yields and dissatisfaction. Moreover, prolonged construction periods affect the credibility of the executing agency, cause administrative challenges, and may even lead to legal disputes or penalties.

8.3 Cost over run

Cost overrun, on the other hand, is often a direct outcome of time overruns. As the project timeline extends, the cost of labor, machinery, supervision, and materials tends to rise, increasing the overall budget beyond original estimates. Price fluctuations in materials like HDPE or DI pipes, fuel, or concrete, along with scope changes or poor planning, further contribute to cost escalation. This leads to financial instability, requiring additional funding, loan adjustments, or scope reduction. In worst cases, essential project components might be compromised to fit within the adjusted budget, affecting the quality and long-term sustainability of the irrigation system.

8.5 key observation for sites

The combined analysis of Salagare Branch Canal and Kalambi Branch Canal reveals critical performance issues across both time and cost parameters. The majority of sites under both projects are facing serious schedule delays and budget overruns, which indicates systemic inefficiencies in planning, execution, and project management. The key observations are-

- Time and cost performance are closely linked—sites with high delays also show high-cost overruns.
- Very low SPI and CPI values (<0.5) at some locations indicate poor planning, ineffective monitoring, and possibly contractor-related inefficiencies.
- A few sites in Kalambi Branch Canal show positive performance, suggesting that best practices are present but not consistently applied.

The current status of both Salagare and Kalambi canal projects reflects project management failures in terms of time control, budgeting, and execution discipline. Without immediate corrective measures—such as resource reallocation, contractor accountability, schedule revision, and use of performance monitoring tools (like EVM)—these projects are likely to face further escalation in cost and delays. All those site affects due to different Delay factors. For different Stockholders.

9 SITE PHOTOGRAPHS CAUSE DELAY IN PROJECT

Natural disaster Change in alignment due to local politics

Failure of crane cause delay in PDN

Accident of crane due to unskilled operator

10 RESULT

The analysis results of the PDN project highlight several key delay factors from the perspective of the Owner/Department. The two most strongly effective issues identified are Delayed Payments and Natural Disasters, which directly impact project momentum. Delayed payments restrict contractors' ability to manage labor and resources effectively, while natural disasters introduce unpredictable disruptions. Other concerns like Late Approvals or Inspections also contribute to project slowdowns, especially during critical phases. To mitigate these delays, the department must improve financial workflows, accelerate approval procedures, and enhance disaster readiness strategies.

From the viewpoint of Contractors and Sub-Contractors, the major delay factors include Local Public and Political Issues, Lack of Skilled Workforce, Subcontractor Delays, and Inadequate Equipment or Tools, each with a very high RII score. These reflect operational challenges, inadequate planning, and weak coordination among teams. Additional issues such as Late Material Delivery and Equipment Failures exacerbate the problem. Contractors must therefore focus on workforce development, efficient subcontractor management, and timely procurement to enhance project execution and prevent timeline extensions.

On the Manufacturer and Supplier side, the analysis reveals that Local Public and Political Issues, Production Delays, and Supply Chain Disruptions are the most impactful factors causing delays. The sector also suffers from a shortage of skilled labor, equipment inadequacies, and strikes, which affect the timely delivery of essential components. Poor packaging and material defects further lead to rework and wasted time.

Strengthening production planning, quality control, and logistics systems is essential to reducing these issues and ensuring that material supply aligns with project schedules.

11 CONCLUSIONS

The analysis of delay factors in the PDN (Pipe Distribution Network) project highlights that each stakeholder group—Owner/Department, Contractors and Sub-contractors, and Manufacturers and Suppliers—faces unique yet interconnected challenges. For the Owner/Department, delayed payments are the most critical, causing a ripple effect on the contractor's ability to execute work efficiently. This financial bottleneck, along with late approvals and the unpredictable impact of natural disasters, underscores the need for stronger administrative control, streamlined processes, and contingency planning. Meanwhile, contractors and sub-contractors struggle with issues like local political interference, shortage of skilled labor, and inadequate equipment—all of which reflect internal mismanagement and external socio-political pressures that hinder project progress and increase costs.

From the Manufacturer and Supplier perspective, major concerns include production delays, equipment shortages, and unreliable supply chains—often worsened by local political disruptions. These factors delay material delivery, leading to idle labor, increased costs, and forced schedule adjustments. Natural disasters are a common and uncontrollable delay factor across all stakeholders due to their unpredictable nature, meaning only assumptions and basic risk measures can be taken. Local public and political problems pose another major threat, driven by personal agendas, lack of awareness, or demands for compensation. These disruptions are often beyond the project team's control and can lead to prolonged work stoppages, making them one of the most difficult challenges in ensuring timely project completion.

11.1 REMEDIAL MEASURES

To avoid such delays in future PDN or similar infrastructure projects, the following remedial measures should be adopted:

1. Timely Payment Mechanisms:

Implement automated billing and clearance systems to ensure payments to contractors and vendors are processed without unnecessary delays.

2. Workforce Development:

Invest in training programs to build a skilled labor force capable of handling specialized irrigation and pipeline works.

3. Improved Project Planning Tools:

Use modern project management software (e.g., Primavera, MS Project) to better schedule, monitor, and control execution.

4. Strong Supply Chain Management:

Establish reliable vendors, maintain buffer stocks, and pre-qualify multiple suppliers to avoid material delays.

5. Contingency Planning:

Develop disaster management and emergency response plans to minimize disruption from natural or political events.

6. Stakeholder Coordination:

Conduct regular review meetings among departments, contractors, and suppliers to track progress and resolve issues early.

7. Efficient Subcontractor Management:

Set clear performance expectations and penalties to ensure subcontractors adhere to timelines and quality standards

8. Quality Assurance Measures:

Ensure all materials are inspected and certified before dispatch to prevent rework due to substandard supplies.

By applying these remedial strategies, future PDN projects can achieve better timeline control, cost efficiency, and overall project success.

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