

# Construction-Management-Oriented Review and Planning of Domestic Water Distribution Networks: A Case Study of Nidhori Village

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## ABSTRACT

Domestic water distribution systems in rural and semi-urban settlements frequently operate with intermittent supply, unequal pressure, ageing assets, manual operation and limited maintenance planning. This research paper is prepared from the Nidhori village domestic water distribution dataset with a focused scope on two objectives: reviewing and analysing the existing domestic water distribution system and integrating construction management principles into water distribution planning. The case network consists of an overhead tank, eight PVC pipe segments and eight principal demand nodes. Pipeline diameter varies from 150 mm to 50 mm, pipe age varies from 6 to 12 years and node elevation decreases from 610 m at the overhead tank to 594 m at the tail end. The observed hydraulic data show that flow reduces from 13.0 L/s at the source to 2.6 L/s at node N8, pressure decreases from 3.0 bar to 0.5 bar, and daily supply duration reduces from 3.0 hours to 1.0 hour. The total calculated domestic demand is 151,500 L/day, while the existing overhead tank capacity is 150,000 L, indicating a narrow storage margin and a small deficit under the baseline demand condition. Leakage varies within approximately 5-12%, with P1 and P8 requiring early attention. The paper proposes a construction-management framework based on work breakdown structure, risk-based pipe prioritisation, resource scheduling, quality control, safety planning and phased implementation. The results show that reliable water service improvement depends not only on hydraulic redesign, but also on organised execution, maintenance sequencing and decision-oriented asset management.

**Keywords:** *Domestic water distribution; construction management; hydraulic review; leakage control; pipe prioritisation; Nidhori village.*

## 1. INTRODUCTION

Domestic water distribution is a critical component of public health, settlement development and infrastructure service quality. In many Indian rural and semi-urban settlements, water reaches households through overhead storage tanks, gravity-fed PVC or HDPE pipelines, manually operated valves and short daily supply windows. Such systems may appear simple, but their performance is strongly affected by pipe diameter, pipe age, elevation difference, friction losses, leakage, demand distribution and maintenance quality. International and Indian literature on water utilities identifies non-revenue water, deteriorating assets, uneven pressure and intermittent supply as continuing barriers to reliable domestic service [1]. Therefore, a domestic water distribution network should be assessed not only as a hydraulic layout but also as an infrastructure project requiring planning, scheduling, inspection and operational control [2]. The earlier complete research paper on Nidhori village considered construction management and machine learning together. This requires evaluation of network geometry, node elevation, flow rate, pressure, supply duration, water demand, leakage and storage adequacy. Objective 2 is to integrate construction management principles into water distribution planning. This requires transforming technical deficiencies into implementable field actions such as pipe repair, replacement, work packaging, labour-material planning, quality assurance, safety control and phased scheduling [3].

Recent studies have demonstrated that smart water systems benefit from data analytics, sensor-based monitoring, hydraulic modelling and predictive decision support [4]. However, a major limitation in many village-level projects is that analytical recommendations are not always linked with construction execution planning. For example, identification of a low-pressure pipe section has limited practical value unless it is converted into a priority work item with quantity estimation, procurement timing, manpower planning and service-disruption control. Construction management research

similarly shows that digital workflows, coordinated underground infrastructure management and project scheduling can reduce delay, rework and resource waste [5]. This paper therefore treats domestic water planning as a combined engineering and management task [6].

The selected case study is Nidhori village, Taluka Kagal, District Kolhapur, Maharashtra. The available dataset includes pipe characteristics, node elevation, hydraulic parameters, household demand and construction management indicators. The main contribution of the paper is an objective-wise interpretation of the existing water network and a practical construction-management framework for improvement [7]. The paper avoids unnecessary expansion into advanced prediction models and instead emphasises the measurable conditions that directly support planning decisions. This makes the study more useful for local bodies, engineers, contractors and project managers who must upgrade an existing water network with limited resources and minimum disturbance to daily household supply [8].

## 2. RELATED WORK

Research on domestic water distribution networks shows that service reliability depends on hydraulic adequacy, asset condition and operational management. Pesantez [9] highlighted the role of computational frameworks for hazard preparedness and water distribution security. Hangan et al. [10] reviewed ICT-based monitoring solutions and noted that smart water systems require sensing, data handling and decision-support capability. Taloma and Taloma [11] discussed smart meter analytics for intelligent water distribution, while Mumtaz et al. [12] described IoT-enabled automation for water security. These studies collectively indicate that even conventional domestic systems must be supported by structured data and monitoring if service equity is to be improved. Machine learning and data-based methods have been widely applied for leakage detection, pipe-failure assessment, demand forecasting and water-quality classification. Hu et al. [13] used an integrated CF-SVM model for pipeline rupture risk prediction. Komba et al. [14] proposed a hybrid SVM-Random Forest approach for leak detection in water distribution networks. Tanchangya et al. [15] reviewed deep learning applications in modern water systems, while Drogkoula et al. [16] described machine learning methods for sustainable water resource management. Although the present paper does not develop a new ML model, these studies are relevant because they show the importance of measurable indicators such as flow, pressure, leakage and pipe condition for objective decision-making [17].

Construction management literature adds the execution layer required to convert water-system diagnosis into actual improvement work. Piras et al. [18] showed that digital methodologies can reduce construction delay and resource waste. Daulat and Kumar [19] emphasised integrated management of ageing underground infrastructure, which is directly applicable to buried water pipelines. Agostinelli et al. [20] demonstrated that digital-twin approaches can connect infrastructure data with operational analysis at district scale. Du et al. [21] further supported the value of multimodal intelligent systems for building and infrastructure data management. For rural water networks, these principles can be translated into work breakdown structure, risk register, procurement planning, resource balancing and maintenance scheduling [22]. The reviewed literature indicates a clear gap between hydraulic assessment and construction execution in many domestic water studies. A pipe may be reported as undersized or a node may be reported as low-pressure, but the study may not specify how repairs should be prioritised, what work package should be executed first, or how materials and labour should be sequenced. This paper addresses that gap using the Nidhori village data. It first reviews the existing domestic water distribution system and then integrates construction management principles into a practical planning framework. The framework is not limited to pipe replacement; it also includes leakage control, storage-margin evaluation, tail-end reliability, inspection frequency and site-level implementation control.

## 3. RESEARCH METHOD AND OBJECTIVE-WISE FRAMEWORK

The research method follows a quantitative case-study approach. The input dataset was organised into five groups: physical network data, node-elevation data, hydraulic performance data, demand data and construction management indicators. Physical network data include pipe ID, start node, end node, length, diameter, material, installation year, age and condition. Hydraulic data include flow rate, pressure and supply duration at the overhead tank and downstream nodes. Demand data include household count, population, daily demand and per capita demand. Construction management indicators include pipe age, leakage, condition, service priority and maintenance status.

The methodological logic is shown in Fig. 1. First, the existing system is reviewed using measured and tabulated field values. Second, hydraulic and demand deficiencies are identified through comparative interpretation. Third, pipe-related

problems are converted into construction management work items. Fourth, work items are prioritised using risk-based reasoning. Finally, the recommendations are organised into a phased implementation plan. The method is intentionally practical because the selected water network is an existing village system, where improvement must be achieved through manageable field actions rather than complete reconstruction.

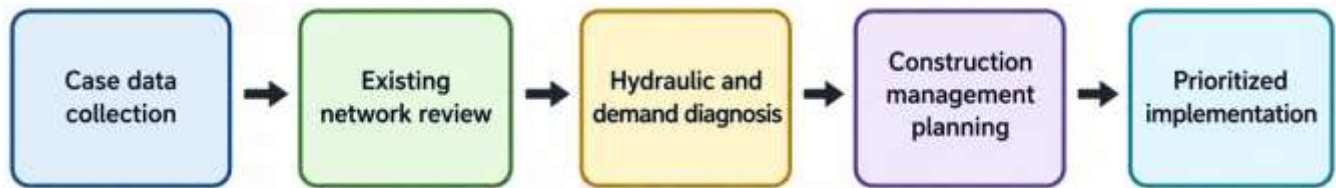


**Fig. 1: Research and Planning Framework**

Fig. 1 shows that the study starts with case-data collection and proceeds toward existing-system review, hydraulic diagnosis, construction-management planning and implementation prioritisation. The figure directly connects Objective 1 and Objective 2. The first three boxes support review and analysis of the current domestic water distribution system, while the last two boxes show how technical findings are converted into project-management actions. This workflow is suitable for village-level water supply because it supports incremental improvement, resource control and risk-based sequencing instead of a costly complete redesign.

#### 4. CASE STUDY DATA OF NIDHORI DOMESTIC WATER DISTRIBUTION SYSTEM

Nidhori village uses an overhead tank-based domestic water distribution system with PVC pipeline branches. The system is topographically favourable for gravity supply because elevation decreases from the source towards the tail-end nodes. However, a favourable elevation gradient does not automatically ensure equitable service. In the present dataset, flow, pressure and supply duration reduce sharply along the network. This indicates that pipe diameter reduction, friction losses, leakage, ageing assets and operational scheduling affect the service level experienced by downstream users.

Table 1 summarises the main pipeline characteristics used for review. Pipe length varies from 200 m to 450 m and diameter varies from 50 mm to 150 mm. P1 is the primary line from the overhead tank to N1 and has the highest diameter, while P5, P6 and P8 are smaller branch-level pipes of 50 mm diameter. Pipe age ranges from 6 to 12 years. P1 and P8 are the oldest assets, and P7 and P8 are classified as poor in the validation dataset. These values make pipe prioritisation essential because maintenance decisions should be based on age, condition, leakage and service importance together.

**Table 1: Pipeline Network Characteristics and Condition**

| Pipe ID | Start | End | Length (m) | Dia. (mm) | Material | Age (yrs) | Condition |
|---------|-------|-----|------------|-----------|----------|-----------|-----------|
| P1      | OHT   | N1  | 450        | 150       | PVC      | 12        | Moderate  |
| P2      | N1    | N2  | 300        | 100       | PVC      | 10        | Moderate  |
| P3      | N1    | N3  | 280        | 75        | PVC      | 9         | Good      |
| P4      | N2    | N4  | 220        | 75        | PVC      | 8         | Good      |
| P5      | N3    | N5  | 200        | 50        | PVC      | 6         | Good      |
| P6      | N4    | N6  | 260        | 50        | PVC      | 7         | Moderate  |
| P7      | N5    | N7  | 300        | 75        | PVC      | 11        | Poor      |
| P8      | N6    | N8  | 320        | 50        | PVC      | 12        | Poor      |

Table 1 establishes the physical backbone of the Nidhori network. The major observation is the reduction of diameter from 150 mm at the primary pipe to 50 mm in downstream branch pipes. The oldest pipes are P1 and P8, while P8 also combines small diameter and poor condition. P7 and P8 therefore represent high attention points for construction planning, while P1 is important because it is the main transmission pipe from the overhead tank. The uniform PVC material simplifies procurement and repair planning, but the age and condition variation require risk-based prioritisation rather than uniform rehabilitation.

**Table 2: Node-Wise Hydraulic, Elevation and Demand Data**

| Node | Elev. (m) | Flow (L/s) | Pressure (bar) | Supply (h/day) | Population | Demand (L/day) |
|------|-----------|------------|----------------|----------------|------------|----------------|
| OHT  | 610       | 13.0       | 3.0            | 3.0            | -          | -              |
| N1   | 608       | 12.5       | 2.8            | 3.0            | 600        | 30,000         |
| N2   | 606       | 10.8       | 2.3            | 3.0            | 500        | 25,000         |
| N3   | 605       | 9.2        | 2.0            | 2.5            | 450        | 22,000         |
| N4   | 603       | 7.1        | 1.5            | 2.0            | 400        | 20,000         |
| N5   | 600       | 5.8        | 1.2            | 2.0            | 350        | 17,500         |
| N6   | 598       | 4.3        | 0.9            | 1.5            | 300        | 15,000         |
| N7   | 596       | 3.1        | 0.6            | 1.0            | 250        | 12,000         |
| N8   | 594       | 2.6        | 0.5            | 1.0            | 200        | 10,000         |

Table 2 combines the principal variables required for Objective 1. Elevation decreases from 610 m at the overhead tank to 594 m at N8, creating a total elevation difference of 16 m. Despite this gravity advantage, flow decreases from 13.0 L/s to 2.6 L/s, pressure decreases from 3.0 bar to 0.5 bar and supply duration decreases from 3.0 hours per day to 1.0 hour per day. This confirms that the existing system is not only topographically dependent but also affected by network losses, diameter constraints and operational imbalance.

## 5. ANALYSIS OF THE EXISTING DOMESTIC WATER DISTRIBUTION SYSTEM

The first objective is addressed by examining the present water distribution system as a functioning but imbalanced domestic network. The upstream portion near the overhead tank and N1 receives comparatively higher flow and pressure. The downstream portion, particularly N6, N7 and N8, receives lower flow, lower pressure and shorter daily supply duration. Such a decline is common in branched gravity systems, but the magnitude observed in Nidhori is significant for household service. When supply duration is only one hour at the tail end, even small leakage or valve-operation delays can reduce the practical water received by users.

Fig. 2 compares flow, pressure and supply duration across nodes. The trend is continuous and downward, which indicates that the problem is system-wide rather than restricted to one isolated node. Pressure at N8 is only 0.5 bar, and supply duration is only 1.0 hour per day. These values are weaker than upstream service and show the need for tail-end pressure monitoring, leakage control and operational scheduling. The figure also shows that N1 and N2 have relatively stronger hydraulic conditions, meaning that improvement resources should be concentrated where actual service deficiency is higher rather than distributed uniformly.

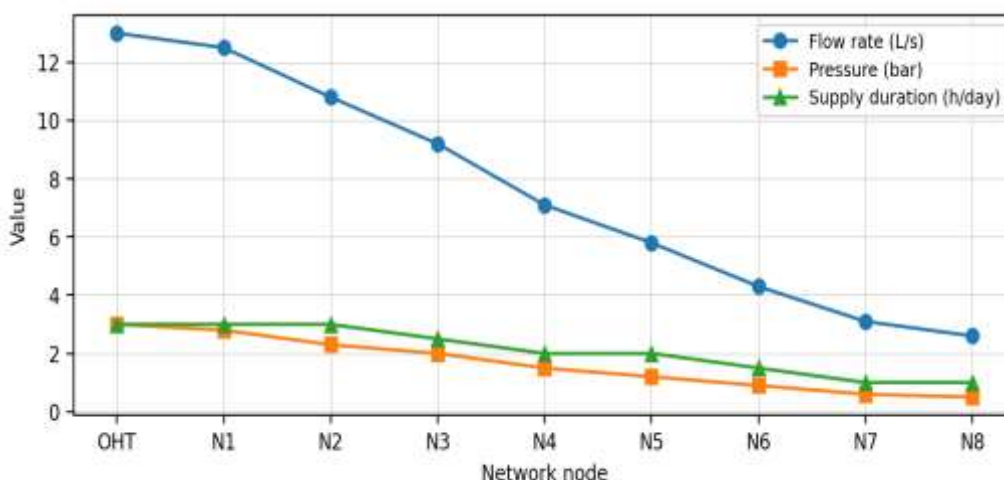


**Fig. 2: Hydraulic Decline Across Nidhori Nodes**

Fig. 2 clearly shows that the system loses hydraulic strength from the source to the tail end. Flow rate decreases by about 80.0% from OHT to N8, while pressure decreases by about 83.3%. Supply duration decreases by 66.7%. These reductions are critical because a domestic water network must be judged by user-level delivery rather than source-level

capacity alone. The graph supports Objective 1 by demonstrating that the existing system requires targeted diagnosis, not only general description. Demand analysis shows that the total domestic demand across nodes N1 to N8 is 151,500 L/day. The available overhead tank capacity is 150,000 L. The baseline storage deficit is therefore 1,500 L/day, which is approximately 0.99% of the calculated demand. Although this deficit appears small, it becomes more serious when leakage, peak-hour demand, storage drawdown and intermittent scheduling are considered. The system is therefore operating with a very narrow storage margin. Under such conditions, reducing water loss can provide almost the same practical benefit as increasing storage, especially when capital funds are limited.

The demand distribution also shows that N1 and N2 carry the highest population and demand loads. However, tail-end nodes cannot be ignored simply because their demand is lower. N7 and N8 represent hydraulic disadvantage zones because they receive lower pressure and shorter supply. This means planning should combine demand volume and service equity. High-demand nodes require volume adequacy, while low-pressure nodes require reliability protection. A simple uniform distribution approach is therefore not suitable for the observed network.

**Table 3: Demand, Population and Pipe-Diameter Adequacy Indicators**

| Node | HH  | Pop. | Demand (L/day) | LPCD | Dia. (mm) |
|------|-----|------|----------------|------|-----------|
| N1   | 120 | 600  | 30,000         | 50   | 150       |
| N2   | 100 | 500  | 25,000         | 50   | 100       |
| N3   | 90  | 450  | 22,000         | 49   | 75        |
| N4   | 80  | 400  | 20,000         | 50   | 75        |
| N5   | 70  | 350  | 17,500         | 50   | 50        |
| N6   | 60  | 300  | 15,000         | 50   | 50        |
| N7   | 50  | 250  | 12,000         | 48   | 75        |
| N8   | 40  | 200  | 10,000         | 50   | 50        |

Table 3 indicates that pipe adequacy cannot be decided only from population. N1 has the highest demand and is connected to the largest pipe, while several downstream nodes operate through smaller pipes. N5, N6 and N8 are particularly important because 50 mm branch pipes coincide with reduced hydraulic performance. The table supports demand-sensitive planning: central nodes require sufficient volume transmission, whereas tail-end nodes require pressure preservation and longer effective service duration. These observations justify a construction-management approach that packages works by priority rather than by simple geographical order.

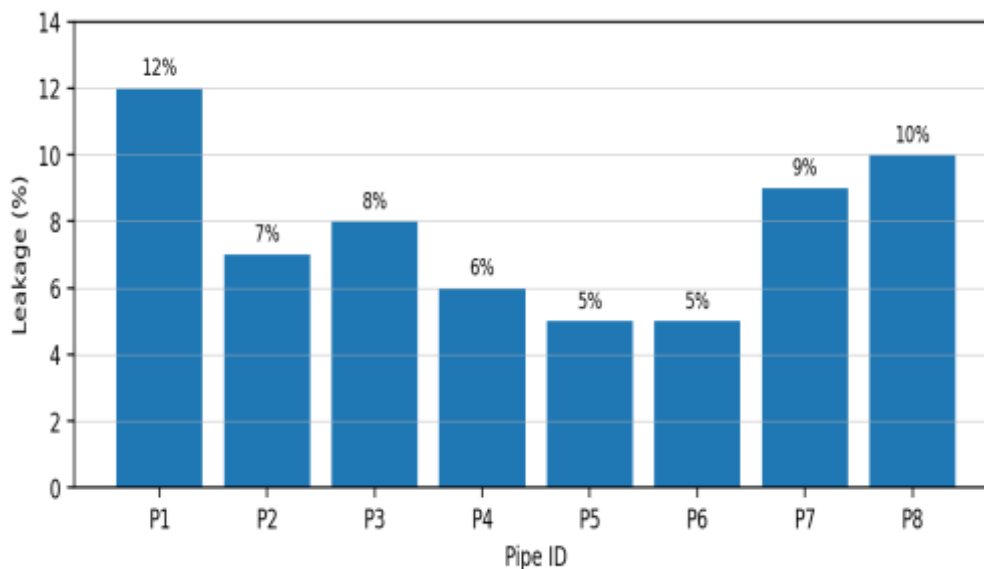


**Fig. 3: Pipe-Wise Leakage Level for Priority Review**

Fig. 3 identifies leakage as a major operational weakness. P1 has the highest leakage level at 12%, followed by P8 at 10% and P7 at 9%. P1 leakage is critical because it occurs near the source and can reduce supply to the whole system. P8 leakage is critical because it affects the tail end, where pressure and supply duration are already weak. Therefore,

leakage control should follow a dual strategy: repair high-loss upstream segments to protect total system volume and repair tail-end losses to improve service equity.

## 6. INTEGRATION OF CONSTRUCTION MANAGEMENT WATER DISTRIBUTION PLANNING

The second objective requires converting hydraulic and asset deficiencies into construction management decisions. In practical water distribution projects, analysis alone is insufficient. Every identified issue must be translated into a clear work package with location, scope, quantity, resource requirement, risk level, quality check and execution sequence. For Nidhori, the main construction management actions include pipe leakage repair, poor-condition pipe replacement, tail-end pressure monitoring, valve-operation improvement, storage-margin management and planned maintenance. A suitable construction management framework for this case should include six principles. First, scope definition should identify the exact pipe and node requiring work. Second, work breakdown structure should separate survey, excavation, shutdown planning, material procurement, repair/replacement, pressure testing, backfilling and reinstatement. Third, scheduling should minimise disruption to daily household supply. Fourth, resource planning should ensure availability of PVC pipe sections, fittings, labour, excavation tools and safety equipment. Fifth, quality assurance should verify jointing, pressure testing and leakage closure. Sixth, monitoring should record post-intervention pressure, flow and supply duration. These principles are consistent with digital construction and underground infrastructure management literature [15], [21], [23].

Table 4 converts the observed technical issues into planning actions. This table is important because it bridges the gap between engineering diagnosis and site execution. It allows local engineers and project managers to identify which problem should be treated as an immediate maintenance item, which problem should be scheduled as a replacement project, and which problem should be monitored before capital expenditure is committed.

**Table 4: Construction-Management Conversion Deficiencies**

| Issue                 | Location   | Observed basis                  | Priority |
|-----------------------|------------|---------------------------------|----------|
| Low tail-end pressure | N6-N8      | Pressure 0.9-0.5 bar            | High     |
| Short supply duration | N7-N8      | 1.0 h/day                       | High     |
| High leakage          | P1, P8, P7 | 9-12% leakage                   | High     |
| Poor pipe condition   | P7-P8      | Poor condition                  | High     |
| Storage margin        | OHT        | 150,000 L against 151,500 L/day | Medium   |
| Demand-pipe mismatch  | N5-N8      | Small downstream diameters      | Medium   |

Table 4 shows that construction management is not an external addition but a direct planning response to the reviewed network data. The highest priorities are leakage repair in P1, P7 and P8, tail-end pressure improvement at N6-N8 and replacement of poor-condition downstream pipe sections. Medium-priority works include storage-margin review and pipe-diameter verification. This ranking allows the project to begin with low-cost, high-impact actions before undertaking larger capital works.

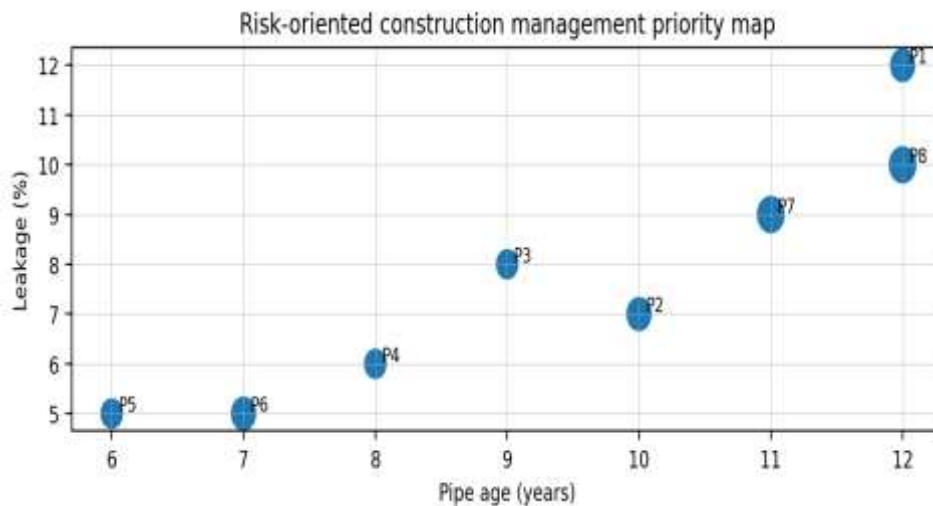


**Fig. 4: Risk-Oriented Pipe Priority Map**

Fig. 4 plots pipe age against leakage to support risk-oriented construction planning. P1 and P8 appear as high-risk items because both are old and show high leakage. P7 also requires attention because it has poor condition and high leakage. This risk map helps avoid random maintenance. Instead, it promotes evidence-based work sequencing, where early activities are assigned to assets that have the greatest influence on total supply reliability and tail-end equity.

**Table 5: Phased Implementation Plan for Construction-Managed Improvement**

| Phase                                | Main work content                                                                    | Management deliverable                                        | Time horizon |
|--------------------------------------|--------------------------------------------------------------------------------------|---------------------------------------------------------------|--------------|
| Phase I: inspection and quick repair | Leak detection at P1, P7, P8; valve check; pressure reading at N6-N8                 | Leakage register, repair checklist, service disruption notice | Immediate    |
| Phase II: hydraulic restoration      | Pressure testing, joint repair, critical fittings replacement, supply-hour balancing | Test certificates, pressure log, flow confirmation            | Short term   |
| Phase III: asset replacement         | Replace poor-condition or undersized sections after quantity survey                  | BOQ, work order, safety plan, reinstatement report            | Medium term  |
| Phase IV: performance monitoring     | Monthly demand, leakage and pressure review                                          | Maintenance dashboard and decision log                        | Continuous   |

Table 5 proposes a phased approach because uninterrupted domestic water service is difficult during pipeline work. Phase I focuses on rapid inspection and repair to reduce avoidable losses. Phase II restores hydraulic performance through testing and operational correction. Phase III handles replacement where poor condition or insufficient diameter is confirmed. Phase IV institutionalises monitoring so that the system does not return to reactive maintenance. This phased strategy reduces risk, controls cost and improves accountability.

## 7. RESULTS AND DISCUSSION

The objective-wise results confirm that Nidhori's domestic water distribution network is physically functional but service-imbalanced. The system has an advantageous source-to-tail elevation difference of 16 m, but hydraulic indicators decline sharply along the network. Flow reduces from 13.0 L/s at the OHT to 2.6 L/s at N8. Pressure reduces from 3.0 bar to 0.5 bar. Supply duration reduces from 3.0 hours per day to 1.0 hour per day. These values show that the problem is not absence of source infrastructure but loss of service quality across the distribution path. The demand analysis shows a total calculated requirement of 151,500 L/day against a storage capacity of 150,000 L. This creates a small but important baseline deficit of 1,500 L/day. Because the system also experiences leakage of approximately 5-12%, the effective deficit can increase during operation. Construction management should therefore prioritise non-revenue water

reduction before recommending major new storage. Repairing P1 can improve upstream volume availability, while repairing or replacing P8 can improve tail-end reliability.

Pipe condition and diameter assessment indicate that downstream sections require special attention. P7 and P8 are marked as poor, and P8 also combines 12 years of service, 50 mm diameter and 10% leakage. P1 is also old and has the highest leakage, but it is classified as moderate rather than poor, indicating that condition is influenced by maintenance history and operating stress, not age alone. Therefore, asset management should combine condition, leakage, age, hydraulic effect and user impact. The construction-management integration produces a practical improvement pathway. Instead of proposing an immediate full-network replacement, the paper recommends a staged plan: rapid leak survey, tail-end pressure verification, targeted repair, pressure testing, selective pipe replacement and continuous monitoring. This approach is suitable for a village network because it reduces cost, avoids unnecessary excavation and protects household supply continuity. It also makes the project measurable because every intervention can be linked to a post-work indicator such as reduced leakage, increased pressure, longer supply duration or fewer emergency complaints.

The major discussion point is that domestic water distribution planning must move from reactive repair to planned asset management. In a reactive system, maintenance begins after users report low pressure, burst pipes or poor supply. In a construction-managed system, pipe age, leakage, condition and hydraulic data are reviewed before failure becomes severe. This is the main value added by Objective 2. It does not replace hydraulic design; rather, it ensures that hydraulic findings are implemented through controlled field execution.

**Table 6: Objective-Wise Findings and Planning Implications**

| Indicator              | Observed result                       | Finding                  | Planning implication                          |
|------------------------|---------------------------------------|--------------------------|-----------------------------------------------|
| Flow condition         | 13.0 L/s at OHT to 2.6 L/s at N8      | Tail-end flow deficiency | Monitor and restore downstream hydraulic path |
| Pressure condition     | 3.0 bar at OHT to 0.5 bar at N8       | Pressure inequity        | Tail-end pressure checks and leakage repair   |
| Supply duration        | 3.0 h/day to 1.0 h/day                | Service inequity         | Zone-wise supply scheduling                   |
| Demand-storage balance | 151,500 L/day demand vs 150,000 L OHT | Narrow margin            | NRW reduction before capacity expansion       |
| Leakage                | 5-12% across key pipes                | Physical water loss      | Prioritise P1, P7 and P8                      |
| Pipe condition         | P7 and P8 poor                        | Asset deterioration      | Replacement package after verification        |

Table 6 summarises the objective-wise outcome. Objective 1 identifies the major performance problems: declining flow, declining pressure, unequal supply hours, narrow storage margin, leakage and poor downstream pipe condition. Objective 2 converts these problems into planning implications: monitoring, leakage repair, scheduling, non-revenue water reduction and selective replacement. This demonstrates the central argument of the paper: a domestic water distribution network improves most effectively when engineering diagnosis and construction management execution are treated as one integrated process.

## 8. CONSTRUCTION MANAGEMENT PLANNING RECOMMENDATIONS

For practical implementation, the proposed improvement programme should be organised through a work breakdown structure. A WBS prevents vague recommendations such as 'repair leakage' from remaining unexecuted. Each improvement item should be broken into survey, quantity measurement, shutdown arrangement, excavation, replacement or repair, jointing, pressure testing, backfilling, surface restoration and post-work monitoring. This structure creates responsibility at each stage and supports better coordination between the gram panchayat, engineers, contractors and residents. The first recommendation is to conduct a rapid technical audit of P1, P7 and P8. P1 is important because it is the primary transmission segment; loss at this pipe affects the entire downstream system. P7 and P8 are important because they have poor condition and serve weaker downstream zones. The second recommendation is to establish a node-wise hydraulic record at N6, N7 and N8 because these nodes represent the most vulnerable service condition. The

third recommendation is to prepare a short-term supply balancing plan so that the tail-end users receive a verified supply period rather than only residual supply after upstream withdrawal.

The fourth recommendation is to use staged procurement. Instead of buying material for full-network replacement, the local body can begin with pipe fittings, clamps, valves and testing equipment for high-priority repair. Replacement pipes for P7 or P8 can be procured after a quantity survey confirms the exact damaged length. This reduces dead inventory, avoids unnecessary expenditure and makes the project more financially manageable. The fifth recommendation is to use acceptance criteria for every completed activity. For example, a repaired pipe should not be accepted until pressure testing and post-repair leakage checking are completed. This is essential because poor-quality repair can recreate the same leakage within a short period.

**Table 7: Work Breakdown Structure for Water-Distribution Improvement**

| WBS stage                    | Purpose                                                         | Main resources                            | Expected output                              |
|------------------------------|-----------------------------------------------------------------|-------------------------------------------|----------------------------------------------|
| 1. Survey and diagnosis      | Confirm leakage, pressure and pipe condition                    | Engineer, plumber, helper, pressure gauge | Pipe-wise defect register                    |
| 2. Work packaging            | Separate P1 repair, P7-P8 replacement and node monitoring tasks | Junior engineer, supervisor               | Approved work package and schedule           |
| 3. Procurement               | Arrange PVC pipes, bends, valves, couplers and repair clamps    | Store keeper, contractor                  | Material receipt and quality check           |
| 4. Execution                 | Excavation, repair/replacement, jointing and backfilling        | Skilled labour, excavator/manual tools    | Completed work with safety compliance        |
| 5. Testing and commissioning | Pressure test and trial supply after repair                     | Engineer, operator, plumber               | Pressure-test record and leakage-free status |
| 6. Monitoring                | Monthly flow, pressure, leakage and complaint review            | Operator, local authority                 | Maintenance log and improvement report       |

Table 7 provides an execution-oriented WBS. It shows that water-distribution improvement is not a single construction activity but a sequence of diagnosis, packaging, procurement, execution, testing and monitoring. This structure improves accountability because each stage has a defined output. It also reduces the risk of incomplete repair because pressure testing and monitoring are treated as mandatory work components rather than optional follow-up activities.

**Table 8: Monitoring and Quality-Control Indicators After Implementation**

| Indicator             | Measurement frequency                                  | Acceptance direction                                       | Management purpose    |
|-----------------------|--------------------------------------------------------|------------------------------------------------------------|-----------------------|
| Flow rate at N6-N8    | Weekly during improvement; monthly after stabilisation | No further decline after repair; improvement from baseline | Hydraulic reliability |
| Pressure at N7-N8     | Before and after each repair package                   | Pressure gain or stable minimum pressure                   | Tail-end equity       |
| Leakage at P1, P7, P8 | After repair and during monthly inspection             | Visible loss closed and NRW reduced                        | Water saving          |
| Supply duration       | Daily during trial operation                           | Tail-end supply period verified                            | Service delivery      |
| Material quality      | During procurement and installation                    | Correct diameter, joints and fittings used                 | Construction quality  |
| Complaint register    | Weekly for first month, then monthly                   | Reduced low-pressure and no-supply complaints              | User satisfaction     |

Table 8 defines post-implementation monitoring indicators. These indicators are necessary because construction management does not end when a pipe is buried. The improvement must be verified through flow, pressure, leakage,

supply duration and user complaint records. This table also supports future digitalisation because the same indicators can later be connected to smart meters, IoT sensors or GIS-based asset registers. For the current objective-focused study, the table converts technical review into a measurable management system. Risk control is another important part of construction management integration. Water pipeline improvement work can disturb roads, restrict household access, interrupt supply and create safety hazards during excavation. Therefore, every pipe intervention should be supported by a simple risk register. The register should identify the risk source, likely impact, control action and responsible stakeholder. For Nidhori, the highest project risks are unplanned water shutdown, repeated leakage after low-quality jointing, inadequate traffic or pedestrian protection near excavation, delayed material supply and incomplete post-work testing. These risks can be reduced through resident communication, planned shutdown windows, checklists and supervisor-level verification. Cost control should also follow priority-based logic. A full-network replacement would be expensive and may not be required immediately. The better approach is to first reduce leakage in high-impact pipes, verify pressure response and then proceed with selective replacement. This staged method supports financial discipline because each phase can be evaluated before the next investment is approved. It also supports construction productivity because labour and material are deployed where measurable benefit is expected.

## 9. LIMITATIONS AND FUTURE IMPLEMENTATION SCOPE

The main limitation of the present paper is that it is based on the available case-study dataset and does not include a full dynamic hydraulic simulation using EPANET or WaterGEMS. The analysis therefore focuses on the measured and tabulated values of flow, pressure, supply duration, demand, leakage and pipe condition. This is sufficient for objective-wise review and construction management planning, but future work should validate pipe velocity, head loss and pressure recovery under different demand scenarios. A second limitation is that leakage values are treated as planning indicators. In field implementation, leakage should be measured through night-flow analysis, section isolation, pressure drop testing or acoustic inspection. A third limitation is that household demand is calculated using baseline LPCD values and does not include detailed seasonal variation. Future implementation should therefore introduce monthly records of rainfall, temperature, population variation, household storage behaviour and actual consumption. Future scope includes GIS-based pipe mapping, development of a village asset register, preparation of a life-cycle cost model, EPANET calibration, installation of pressure loggers at N6-N8 and use of a digital maintenance dashboard. These additions would strengthen the construction management framework by allowing every repair and replacement action to be linked with location, cost, time, service improvement and long-term asset condition.

## 10. CONCLUSION

This 10-page objective-focused research paper reviewed and analysed the existing domestic water distribution system of Nidhori village and integrated construction management principles into water distribution planning. The review found that the network consists of an overhead tank and eight major PVC pipe segments with diameters from 150 mm to 50 mm and ages from 6 to 12 years. The hydraulic analysis showed a strong decline from the source to the tail end: flow decreased from 13.0 L/s to 2.6 L/s, pressure decreased from 3.0 bar to 0.5 bar and supply duration reduced from 3.0 hours to 1.0 hour per day. The calculated domestic demand was 151,500 L/day against an available overhead tank capacity of 150,000 L, indicating a narrow storage margin and a baseline deficit of 1,500 L/day. Leakage levels of about 5-12% and poor pipe condition at P7 and P8 show that service improvement should begin with targeted leakage control and asset renewal. The construction management framework proposed in the paper converts hydraulic deficiencies into work packages, priority ranking, resource planning, quality checks and phased implementation. The most important early actions are P1 leakage repair, P7-P8 condition verification, P8 replacement planning, N6-N8 pressure monitoring and supply-duration balancing. The study concludes that water distribution improvement should not rely only on new construction or storage expansion. A more economical and reliable strategy is to combine existing-system review, demand-service analysis, leakage prioritization and construction-management-based execution.

## REFERENCES

- [1] R. L. Taloma, Jr. and R. L. Taloma, "Advancements in IoT and LPWAN technologies for smart meter data analytics in intelligent water distribution systems: A comprehensive application-oriented review," *Smart Water Systems Journal*, vol. 18, no. 2, pp. 112-140, 2025.
- [2] P. Li, L. Zhang, and F. Wu, "A smart energy-water systems framework based on Deep Q-Networks and multi-objective evolutionary optimization," *Energy Informatics*, vol. 12, no. 3, pp. 221-245, 2025.
- [3] Z. Hu, J. Chen, and Y. Zhao, "Integrated CF-SVM modelling for pipeline rupture risk prediction in urban water distribution networks," *Urban Water Journal*, vol. 33, no. 2, pp. 190-214, 2025.
- [4] C. Cui, S. Liu, and Q. Huang, "A hierarchical coordination-equilibrium framework for evaluating water supply-demand relationships," *Water Resources Management*, vol. 39, no. 4, pp. 455-482, 2025.
- [5] N. Mumtaz, R. Ali, and T. Siddiqui, "IoT-enabled automation for enhancing water security," *Journal of Water Process Engineering*, vol. 58, Art. no. 104672, 2025.
- [6] F. A. S. Islam, T. Rahman, and S. Hossain, "AI-driven predictive modelling for potable water quality classification," *Environmental Monitoring and Assessment*, vol. 197, no. 3, pp. 77-95, 2025.
- [7] T. Tanchangya, M. Hossain, and N. Roy, "Deep learning applications in modern water systems," *Journal of Water Informatics and Intelligence*, vol. 9, no. 1, pp. 55-88, 2024.
- [8] Y. Asadi, "Handling class imbalance in predictive modelling of water pipe failures using XGBoost," *Infrastructure Analytics Journal*, vol. 5, no. 1, pp. 44-63, 2024.
- [9] G. M. Komba, M. Hassan, and S. Ngoma, "Leak detection in water distribution networks using hybrid SVM-Random Forest ensemble learning," *Water Supply*, vol. 24, no. 1, pp. 96-115, 2024.
- [10] D. Du, H. Chen, and Y. Wang, "Multimodal intelligent building systems for smart energy optimization," *Building and Environment*, vol. 245, Art. no. 110986, 2024.
- [11] C. H. Perez-Beltran, E. Morales, and F. Diaz, "AI-driven spectroscopic data analysis for water quality prediction," *Chemometrics and Intelligent Laboratory Systems*, vol. 245, Art. no. 104026, 2024.
- [12] G. Piras, L. De Rossi, and M. Marchetti, "Digital methodologies for minimizing construction delays," *Automation in Construction*, vol. 159, Art. no. 105105, 2024.
- [13] M. Drogkoula, A. Papadopoulos, and S. Vrohides, "Machine learning methodologies for sustainable water resource management," *Environmental Modelling & Software*, vol. 162, Art. no. 105643, 2023.
- [14] R. Bhavya, A. Sharma, and K. Rao, "Applications of ant colony optimization in hydrology," *Journal of Hydroinformatics*, vol. 25, no. 2, pp. 233-270, 2023.
- [15] S. Daulat and R. Kumar, "Integrated management of aging underground urban infrastructures," *Tunnelling and Underground Space Technology*, vol. 122, Art. no. 104399, 2022.
- [16] A. Hangan, R. Ionita, and D. Popescu, "ICT solutions for smart water resource monitoring," *Journal of Hydroinformatics*, vol. 24, no. 6, pp. 1177-1199, 2022.
- [17] S. Agostinelli, F. Bianchi, and P. Rossi, "Digital-twin-based energy optimization for smart residential districts," *Future Cities and Environment*, vol. 7, no. 1, Art. no. 4, 2021.
- [18] J. E. Pesantez, "Computational modelling frameworks for hazard preparedness in water distribution systems," *Journal of Water Resources Planning and Management*, vol. 146, no. 7, Art. no. 04020043, 2020.
- [19] Central Public Health and Environmental Engineering Organisation, *Manual on Water Supply and Treatment and Domestic Water Supply Norms*. New Delhi, India: Ministry of Housing and Urban Affairs, Government of India, 2022.
- [20] Bureau of Indian Standards, *IS 1172: Code of Basic Requirements for Water Supply, Drainage and Sanitation*. New Delhi, India: Bureau of Indian Standards, 2019.
- [21] United Nations, *United Nations World Water Development Report 2023: Partnerships and Cooperation for Water*. Paris, France: UNESCO, 2023.
- [22] World Bank, *Reducing Non-Revenue Water and Improving Water Utility Performance*. Washington, DC, USA: World Bank Water Global Practice, 2022.