भारतीय मानक
Indian Standard

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पेयजल आपूर्ति प्रणाली की परिसंपत्तियों के प्रबंधन — दिशानिर्देश

Management of Assets of Drinking Water Supply System — Guidelines

ICS 13.060.20, 91.140.60

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Drinking Water Supply, Wastewater and Stormwater Systems and Service Sectional Committee, SSD 14

FOREWORD

This Indian Standard was adopted by the Bureau of Indian Standards, after the draft finalized by the Drinking Water Supply, Wastewater and Stormwater Systems and Services Sectional Committee had been approved by the Service Sector Division Council.

The assets of drinking water supply system such as waterworks, building structure, mechanical installations, treatment facilities/processes (filters, sedimentation etc), piped installation, electrical/electronic installation/equipment, storage tanks etc, collectively form the physical infrastructure of drinking water supply system and are the consequence of the accumulated capital investments and operational expenditures on maintenance and rehabilitation. Many times, the replacement value of these past investments amount to heavy expenditure depending on the size of the community being served.

This standard is formulated within the overall concept of management of assets and focuses on the details of managing the physical assets at the operational level rather than the organizational (corporate management, structural or process) level. This standard is intended to provide guidance on the assets typically owned or operated by drinking water utility engaged in collection, treatment, pumping, storage and distribution of drinking water and are expected to meet customer needs and expectations over longer periods.

This standard provides the guidelines to collect and process reliable inventory, historical process, failure and operational data about technical assets of drinking water supply system. A reliable database that supports analysis of failures and of operational data (including a description of the condition of facilities or units) is of particular significance when establishing a risk-based investigation to determine priorities for maintenance and rehabilitation. The data provided should be used for systematic management of assets and benchmarking purposes.

While preparing the standard, assistance has been taken from the following:

a) ISO 24516-2 : 2016 'Guidelines for the management of assets of water supply and wastewater systems — Part 2: Waterworks; and
b) Operation and Maintenance of Water Supply Systems published by Central Public Health and Environmental Engineering Organization (CPHEEO), Ministry of Housing and Urban Affairs, New Delhi.

The composition of the committee responsible for the formulation of this standard is listed in Annex C.

Indian Standard

MANAGEMENT OF ASSETS OF DRINKING WATER SUPPLY SYSTEM — GUIDELINES

1 SCOPE

This standard provides the guideline on technical aspects, tools and good practices for the management of assets of drinking water supply system to maintain value from all existing assets.

NOTES

1 This standard is applicable for all the components of drinking water supply system such as waterworks, treatment facilities, pumping stations, dosing equipment, metering, pipe and fittings, distribution system and storage reservoirs etc.
2 Depending on the size and structure of a drinking water supply system, the utility can decide to what extent it applies the guidance in this standard.
3 The procedures described in this standard can be applied in any drinking water supply system, but detailed application should take account of the age, location and type of the system, the materials used in its construction, together with functional and climatic factors.

2 REFERENCES

The standard listed below contains provisions which, through reference in this text, constitute provisions of this standard. At the time of publication, the edition indicated was valid. The standard is subject to revision, and parties to agreements based on this standard are encouraged to investigate the possibility of applying the most recent edition of the standard listed below:

IS No.	*Title*
IS 10500 : 2012	Drinking water — Specification (*second revision*)

3 TERMINOLOGY AND SYMBOLS

3.1 Terminology

For the purposes of this standard, the following terms and definitions shall apply.

3.1.1 *Asset* — Any entity that has potential or actual value to a drinking water utility.

NOTES

1 Assets are used in a drinking water utility for the provision of the service.
2 Value can be tangible or intangible, financial or non-financial, and includes consideration of risks and liabilities. It can be positive or negative at different stages of the asset life.
3 Physical assets usually refer to equipment, inventory and properties for examples land, buildings, pipes, valves, wells, tanks, treatment plants, equipment, water meter, hardware etc. Intangible assets are the non-physical assets such as leases, brands, digital assets, use rights, licenses, intellectual property rights, water rights, software, databases, reputation or agreements.
4 Contrary to consumables, assets can be depreciated in accounting systems.

3.1.2 *Asset System* — Set of assets that interact or are interrelated.

NOTE — A grouping of assets referred to as an asset system could also be considered as an asset.

3.1.3 *Drinking Water Supply System* — System providing the functions of abstraction, transportation, treatment, storage, distribution and supply of drinking water.

3.1.4 *Distribution System* — System providing the function of distribution of drinking water to the end users.

NOTE — It can include pipes, valves, hydrants, washouts, pumping stations, storage reservoirs, metering and ancillary infrastructure, and components.

3.1.5 *Emergency Operation Plan* — Document specifying the procedures and associated resources to be applied by whom and where during a particular type of emergency.

3.1.6 *Failure* — Local inadmissible impairment of the operability of an asset of a drinking water supply system at a certain point in time.

3.1.7 *Failure Data* — Data describing the characteristics of the failure caused at a certain point in time on a certain asset of a drinking water supply system.

3.1.8 *Failure Rate* — Ratio of the number of failures of a given category to a given unit of measure.

NOTE — The entity to define failure rate for different category of assets could be different such as:

a) for pipelines it is expressed as failure per kilometer within a year;
b) for pumps it is number of times pump fails per year;
c) for connections and valves in relation to drinking water distribution networks, expressed as failure per thousand per year; and
d) for treatment plants, pumping stations and similar facilities, expressed instances per year.

3.1.9 *Geographic Information System (GIS)* — A computer system for capturing, storing, checking, and displaying data related to positions on Earth's surface.

3.1.10 *Inspection* — Determination of conformity to specified requirements by observation/investigation and judgement accompanied by visual control, handling, measurement, testing or gauging.

3.1.11 *Investigation* — Gathering of all necessary information and process for decision-makers.

NOTE — This includes both qualitative and quantitative information.

3.1.12 *Level of Service* — Parameter, or group of parameters, which reflect social, political, environmental and economic outcomes regarding the service to end users that the drinking water utility delivers.

NOTES

1 The service to users can include any of the following parameters: health, safety, user satisfaction, quality, quantity, capacity, reliability, responsiveness, environmental acceptability, cost and availability.

2 A defined level of service can include any combination of the aforementioned parameters deemed important by the asset owner, users or relevant stakeholders.

3.1.13 *Life Cycle Cost* — Total cost of an asset as a whole or its parts throughout its life cycle.

NOTES

1 Total cost can include planning, design, construction, acquisition, operation, maintenance, rehabilitation and disposal costs.

2 Total cost excludes any residual value obtained during disposal.

3.1.14 *Maintenance* — Combination of all technical, administrative and managerial actions during the life cycle of an asset intended to retain it in, or restore it to, a state in which it can perform the required function.

3.1.15 *Management of Assets* — Processes during the life cycle of an asset necessary to derive value from existing assets while ensuring an agreed level of service and function of the system.

NOTE — Processes include:

a) all necessary activities for planning, design, procurement, construction/installation, commissioning, operation, maintenance, rehabilitation and disposal of assets of drinking water systems as a functional activity, including their review;
b) setting objectives and functional and performance requirements;
c) establishing strategic plans, tactical plans and operational plans; and
d) undertaking investigations, including establishing necessary databases, to assess the actual condition of assets during the lifecycle of the asset system.

3.1.16 *Non-Revenue Water* — It is the difference between the volumes of water supplied and billed authorized use.

NOTE — Non-revenue water includes not only the direct and apparent water loss, but also the unbilled authorized use.

3.1.17 *Operation(s)* — Activities undertaken to maintain the normal functioning of the system.

3.1.18 *Operational Plan* — Documented collection of procedures and information that is developed, compiled and maintained in readiness for the conduct of operations.

3.1.19 *Performance Indicator* — Process parameters with set and prescribed goals of water utility to achieve accuracy.

NOTE — Performance indicators are means to measure the efficiency and effectiveness of process.

3.1.20 *Rehabilitation* — Measures for restoring or upgrading the performance of existing asset, including renovation, repair and replacement.

3.1.21 *Rehabilitation Rate* — Percentage of entire inventory which is rehabilitated or to be rehabilitated on an annual basis.

3.1.22 *Service* — Output of drinking water utility in terms of an activity or set of activities necessarily performed between the drinking water utility and the end users.

NOTES

1 The dominant elements of a service are generally intangible.

2 Service involves activities and processes within the drinking water utility, at the interface with the user, to establish user requirements as well as upon delivery of the service and can involve a continuing relationship.

3 Provision of a service can involves, for example:

a) an activity performed on a user-supplied intangible product like processing new connection requests;
b) delivery of an intangible product like the delivery of information in the context of knowledge transmission; and
c) the creation of ambience for the user in reception offices.

4 A service is generally experienced by the user and can be monitored by one or more stakeholders.

3.1.23 *Service Life* — Period of time after installation during which an asset or an asset system meets the expected technical and functional requirements.

3.1.24 *Strategic Plan* — Document identifying goals and objectives to be pursued by an organization over a long- term period in support of its mission and being consistent with its values.

3.1.25 *Tactical Plan* — Document identifying objectives to be pursued by an organization over the medium term, based on priorities derived from influencing factors/indicators on performance, costs, risk and failure probability and scale of failure.

3.2 Symbols

For the purpose of this Indian Standard, the following symbols shall be used:

X — Applicable
O — Optional

4 UNDERSTANDING THE DRINKING WATER UTILITY

4.1 Objectives

4.1.1 At minimum, the drinking water utility should consider the following objectives:

a) Protection of public health;
b) Meeting users' reasonable needs and expectations;
c) Occupational health and safety;
d) Providing services in usual and emergency situations;
e) Promoting the sustainability of the drinking water utility;
f) Promoting sustainable development of the community; and
g) Protection of the environment.

4.1.2 The drinking water utility while undertaking management of asset, should aim to manage their facilities systematically and efficiently to sustain their function, through establishment of clear objectives, based on assessment and forecasting of the condition of all existing facilities.

4.1.3 During the selection of objective for the management of assets, the drinking water utility should consider the compliance with agreed sustainable levels of service, while also meeting economic performance objectives such as attaining the least possible overall life cycle cost.

NOTE — Refer Annex A for further information on objectives of management of assets for drinking water supply systems.

4.2 Functional Requirements

4.2.1 To achieve the objectives, the drinking water utility should establish functional requirements for the activities undertaken by the utility which can include intake of water from source (catchments, wells and rivers), transmitting (pumping as necessary), storing prior to treatment, treatment upto a specified level, storage of treated water, continuous supply to distribution network (pumping/gravity).

4.2.2 Functional requirements should be considered in respect of the whole system to ensure that additions or modifications to the system sustainability do not result in failure to meet the target.

4.2.3 Functional requirements should be established to ensure that the drinking water supply system do not cause unacceptable environmental nuisance, risk to public health or personnel working therein.

NOTE — Each functional requirement can relate to more than one objective. An indication of the relevance of each of the functional requirements in achieving the objectives is shown in Table 1.

4.3 Performance Requirements

4.3.1 The drinking water utility should determine measurable performance requirements to evaluate the hydraulic, process engineering, structural and operational performance of the drinking water supply systems and to allow development of design standards.

4.3.2 Performance indicators should act as an essential tool in understanding actual and desired performance of infrastructure of drinking water utility, and in parallel, enable indicator-supported infrastructure planning and decision making. Properly implemented, indicators provide information on the condition of the assets and the level of their contribution to the achievement of the utility's objectives.

4.3.3 For each functional requirement, there can be legal requirements, public expectations and financial constraints which can influence the performance requirements. For each aspect of performance, different levels can be required, for example:

a) trigger levels which justify early upgrading action according to priority; and
b) target levels to aim for in upgrading, which should be equal to the requirements for new construction, but which sometimes can only be achievable or necessary in the longer term.

Table 1 Relationship Between Objectives and Functional Requirements
(*Clause* 4.2)
(*Informative*)

Sl No.	Functional Requirements	Objectives						
		Protection of Public Health and Safety	Meeting Users' Reasonable Needs and Expectations	Occupational Health and Safety	Providing Services Under Usual and Emergency Situations	Promoting the Sustainability of the Drinking Water Utility	Promoting Sustainable Development of the Community	Protection of the Environment
(1)	(2)	(3)	(4)	(5)	(6)	(7)	(8)	(9)
i)	Ensuring that the quality of drinking water meets the acceptable limit of IS 10500	XXX	XXX	XX	XX	XX	XX	XX
ii)	Continuity of service	XXX	XXX	—	XXX	XXX	XXX	X
iii)	Ensuring adequate pressure	XXX	XXX	X	XX	XX	—	X
iv)	Maintainability	XX	X	XXX	XX	XX	XX	XX
v)	Providing service under emergency situations	XXX	XXX	X	XXX	XXX	—	XXX
vi)	Sustainability of products and materials	—	XX	—	XX	XXX	—	X
vii)	Sustainable use of energy	—	X	—	XX	XXX	—	XX
viii)	Long design life of assets	X	XX	X	XX	XXX	—	XXX
ix)	Minimizing of leakages	XX	X	X	X	XXX	—	XXX
x)	Minimizing of Failure	XX	X	X	X	XXX	—	XXX
xi)	Prevention of noise	XX	X	X	X	X	—	X
xii)	Not endangering adjacent structures and environment	XX	X	XX	X	XX	—	X

NOTE — The number of X indicates the relevance of the requirement in achieving the objectives.

4.3.4 Performance requirements should be reviewed periodically and updated, if necessary. The performance requirements for the system should be updated after major extension, maintenance, or rehabilitation. In principle, the performance requirements for a rehabilitated system should be the same as those for a new drinking water supply system.

4.3.5 Performance indicator should be defining at strategic, tactic and operation levels. They should make clear how actions at the operational level contribute to achieve strategic level objectives.

NOTES

1 Strategic level performance indicators are often called outcomes. Whereas operational and tactical level performance indicators are called 'inputs' and 'outputs' respectively.

2 Examples of performance indicator includes conformity of drinking water quality, meeting future water supply demand and achieving service level benchmark, meeting peak consumption, optimal use of chemicals, energy and manpower resources etc.

4.4 General Aspects

4.4.1 In management of assets, a distinction should be drawn between two principal focal points:

a) The wider drinking water utility or responsible body in question; and
b) The drinking water supply system to be managed.

4.4.2 The focal point of drinking water utility or responsible body can include, for example, strategic financial, reputational and non-operational assets as part of ensuring the drinking water utility's overall objectives are met.

4.4.3 The focal point of drinking water supply system should include the following:

a) attention to stakeholder requirements, needs and expectations;
b) sustainability of the asset system and the provided service;
c) safe water quality;
d) the management of risk; and
e) financial stability of the utility.

4.5 Principal Aspects

4.5.1 *Principal Aspects — Drinking Water Utility*

Minimizing life cycle costs while continuously providing the levels of service should be established by the drinking water utility to meet customer/stakeholder expectations by adopting effective management of assets. The management of the assets of drinking water utility includes key activities such as:

a) the determination of the current and long-term objectives;
b) planning and implementing activities to achieve objectives;
c) the prediction of future water demand as an additional basis for rehabilitation;
d) the means of measuring the performance of the drinking water utility in meeting these objectives;
e) knowledge of the layout of the entire water supply system together with knowledge on costs (planning, constructing, operation, maintenance etc);
f) knowledge on availability and need of resources;
g) the selection of appropriate materials and components;
h) the choice of installation technology and corresponding contractors;
j) quality control of materials used and of installation;
k) maintenance of assets and asset systems including routine and incident-related inspection and investigation,
m) monitoring of operating conditions;
n) education and training of the personnel to achieve relevant competences;
p) maintaining an up-to-date system inventory;
q) monitoring and documenting data;
r) assessing system condition;
s) planning, maintain or rehabilitating the system;
t) optimizing depreciation and reinvestment;
u) identifying and managing risks; and
v) ensuring the system is utilized/operated as intended, and the environment in which the assets are functioning.

4.5.2 *Principal Aspects — Drinking Water Supply Systems*

4.5.2.1 The services provided by drinking water utility to its users should include following two aspects:

a) Continuous supply of safe drinking water meeting the acceptable limit of IS 10500; and
b) Supporting the fire brigades with water for firefighting if possible (depending on local regulations).

4.5.2.2 In general, drinking water supply system generally comprises five components:

a) Water source;
b) Intake and transport;
c) Treatment if necessary, and if appropriate, disposal of residues;
d) Storage, transport and distribution; and
e) Monitoring of water quality at all critical point of drinking water supply system.

4.5.2.3 The management of assets of drinking water supply systems should cover the complete asset system and the interrelationship of all assets such as waterworks, pumping stations, treatment facilities and distribution network including the resulting water quality.

4.5.2.4 The management of assets should consider changes in needs and expectations/requirements of users and other stakeholders as well as environmental effects such as climate conditions, consumption of resources, population migrations, and demography.

4.5.3 *Integrating the Principal Aspects*

Management of assets within the drinking water supply system should be integrated to the asset management principles of drinking water utility, as described in this standard.

4.6 Risks Aspects

4.6.1 Risk should be considered necessary at strategic, tactic and operation levels with the following principles:

a) Risk identification (in this case, principally by hazard analysis);
b) Risk allocation; and
c) Risk management.

4.6.2 Appropriate treatment of risk arising within the context of drinking water utility should be considered by the introduction, or modification, of existing risk control.

4.6.3 Selection of the most appropriate risk control should result from a process of assessing organizational hazards (arising from asset's positioning or failure). Appropriate countermeasures can then be introduced in a prioritize manner. Such measures can include operation and maintenance activities as well as rehabilitation.

4.6.4 The drinking water utility should define its utility-specific risk analysis approach and criteria for risk evaluation, based on their objectives, and external and internal contexts. Risk criteria should be determined in terms of the same dimensions as the parameters used in the risk analysis. The order of priority for inspection/survey plans should be determined by risk evaluation (which considers the significance of each risk relative to all the risks under consideration). Typically, this comparison is conducted by comparing individual risks 'scores' (the product of a risk's impact and likelihood ratings against the risk criteria), using a risk matrix to present the results.

4.6.5 The prioritization of measures to treat (prevent/reduce) the impact and/or likelihood of individual risks' occurrence should be carried out by comparing the effectiveness of individual treatment measures and their related costs, practicability and acceptability to stakeholders. The outcome of this evaluation process can feed into a wider decision-making process utilizing cost-benefit-analysis techniques (*see* **7.3**).

4.6.6 Drinking water supply system related asset risks can be categorized into the following two groups:

a) Non-influenceable risks, such as natural disasters (earthquakes, storms, floods, etc) or economic situations;
b) Influenceable risks, such as events arising from accidental damage, asset deterioration, mis-operation of assets, or malicious interference with assets.

4.6.7 During the Assessment of impact, the asset data such as sizing, material, operating pressure or function; proximity to other significant assets, infrastructure or areas; access constraints, social influence and repair or rehabilitation cost should be considered.

4.6.8 During the assessment of likelihood impact of failure, the following asset data such as abnormalities of hygiene, exceedance of parametric values, maintenance, telemetry, employees' feedback, details of past incidents, stakeholders' complaints, security, social behaviour and environmental influences should be considered.

4.7 Life Cycle Aspect

Life cycle cost should be minimized by keeping the system in an operating condition as stated in the objectives. This can be achieved by:

a) optimized maintenance planning;
b) investigation/inspection of assets at regular intervals;
c) water loss assessments;

d) use of suitable construction methods and durable materials;
e) cooperation with other services or contractors;
f) energy management;
g) optimized stand-by service;
h) proper control of operational processes;
j) efficient deployment of staff and accomplishment of tasks (by qualified and/or certified contractors, if necessary, while retaining core competences in the utility);
k) participation in benchmarking projects; and
m) demand based materials management and control (procurement and stock keeping).

NOTE — To rehabilitate facilities, the priority of the project should be determined in the framework of budget while aiming to minimize the life cycle cost of each asset.

4.8 Structuring the Process for Management of Assets

4.8.1 Integrated management of assets in drinking water supply system is the process of achieving an understanding of existing and proposed drinking water supply systems and of using this information to develop strategies to ensure that the hydraulic, structural and operational performance meets the specified performance requirements taking into account future conditions and economic efficiency.

4.8.2 The integrated drinking water supply systems management process should have four principal activities:

a) An appropriate level of investigation of all aspects of the performance of the drinking water supply systems;
b) Assessment of the performance by comparison with the performance requirements including identification of the reasons for the performance failures;
c) Developing the plan of measures to be taken; and
d) Implementation of the plan.

The need for further investigation can become apparent either during the performance assessment or the development of the plan.

4.8.3 For large drinking water supply systems an outline integrated drinking water management plan may first be developed following an outline investigation of the whole system. More detailed plans may then be developed for each sub-distribution section within the context of the strategic outline plan.

4.8.4 The integrated drinking water supply systems management plan is further developed during the implementation phase by subsequent investigation, assessment and planning to develop work programs and individual projects to implement the plan. The boundary conditions should also be considered.

4.8.5 The information should be updated regularly for the future management of the drinking water supply systems.

NOTE : Refer Fig.1 for the process flow of integrated drinking water supply system management.

4.9 Strategies for the Management of Assets

4.9.1 While selecting the strategies for the management of asset the drinking water utility should consider the following:

a) objectives, functions and performance requirements;
b) risks involved in not achieving these objectives and performance requirements;
c) design period of drinking water supply systems; and
d) identification of fundamental prerequisites for economically efficient maintenance.

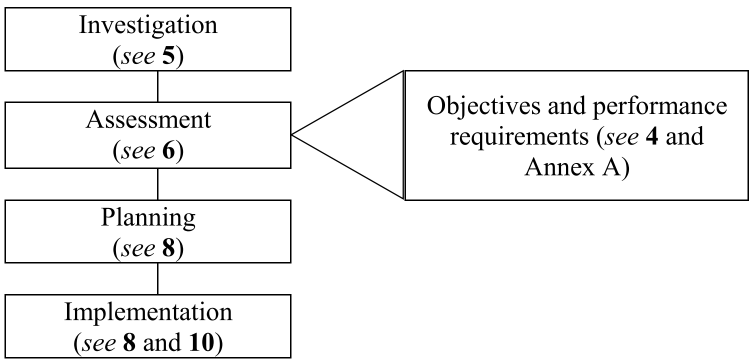


FIG. 1 INTEGRATED DRINKING WATER SUPPLY SYSTEMS MANAGEMENT PROCESS

4.9.2 An appropriate level of care should be exercised during planning on the strategic level due to the very high levels of investment in the drinking water supply system and the technical and financial implications of subsequent adjustments.

4.9.3 Drinking water infrastructure assets should be managed and maintained according to the condition-based or inspection strategy or the incident based or failure strategy. To increase the likelihood of achieving the objectives and requirements, the drinking water infrastructure assets should be managed and maintained according to the condition-based or inspection strategy.

4.9.4 The condition-based or inspection strategy considers the development of the condition of the asset system and single assets and pursues a long-term approach. It warrants the efficient and economical use of restoration funds although it may not reduce overall rehabilitation and life cycle costs over a defined long-term planning period but can spread these costs out over a longer term and can avoid social costs. Costs depend on actual maintenance requirements.

4.9.5 A proactive inspection should enable more efficiencies, though reactive and proactive maintenance need to be appropriately balanced for a particular drinking water utility. A greater level of proactivity and subsequent ability to be more strategic and prioritized in rehabilitation should help a drinking water utility to be more capable of attaining its level of service, as measured by performance indicators.

4.9.6 Organizational constraints, continuance of existing practices or acceptance of the consequences of low- impact risks can lead to use of an incident-based or failure strategy, which incurs lower maintenance costs in the short term but can lead to disproportionally high costs in the long term. Probable consequences can include inadequate operating safety margins, increased failure rates, flooding, and premature loss of the existing structure and value of the infrastructure assets. The risk of failures and inadequacies can be extremely high. An incident-based or failure strategy can usually only be successful if the risk linked to the asset is low and will not be affected by an increased downtime or deficiencies in the water quality.

NOTE — Refer Fig.2 for strategies for management of assets.

4.10 Periods of Planning

4.10.1 *General*

4.10.1.1 The sustainable rehabilitation process for the management of assets should be based on the planning period under review, subdivided into the following three interdependent sub processes:

a) Strategic planning — long-term rehabilitation about 20 to 30 years;
b) Tactical planning — medium-term rehabilitation about 8 to 10 years; and
c) Operational planning — short-term rehabilitation upto 5 years.

NOTE — The duration of the planning stages depends on local circumstances and the nature of the assets.

Increasing intensity of work and degree of details

FIG. 2 LOGICAL STEPS FOR THE IMPLEMENTATION AND EVALUATION OF REHABILITATION TARGETS

4.10.1.2 Asset types should be considered in the ‘strategic planning’ step. In the ‘tactical planning’ step, the required projects should be determined and prioritize for a medium-term period based on an asset evaluation. The technologies and material should be preselected. In the ‘operational planning’ step, the actual execution of the rehabilitation measures in terms of process, material and construction method is then examined and fixed in consideration of possible alternative measures.

4.10.1.3 The sub-processes cannot be considered as independent and their results about rehabilitation strategy, tactics and operational planning should be harmonized not only with one another, but also with the strategic network structure and capacity planning.

4.10.2 *Strategic Level Activities*

The development of the rehabilitation strategy for a long term period should focus the scope of rehabilitation measures and the rehabilitation budgets required to achieve and to maintain sufficient service quality and facility condition levels. It should be based on an asset type approach but not individual asset. In the first step of planning decision making support should require the identification of measurable strategic objectives and the necessary evolution and measurement of the objectives. Common activities related to determining strategic objectives should include the following strategic activities:

a) Establishing acceptable/required levels of service, public safety, public health protection, environmental protection and user satisfaction;
b) Expressing levels in the form of system performance indicators;
c) Linking system performance indicators to asset performance indicator;
d) Establishing adequate billing rates and a water price suitable in time to ensure sustainable revenue;
e) Quantifying sustainable and predictable infrastructure funding requirements;
f) Assessing capacity against future demands;
g) Establishing effective risk control measures and necessary levels of resilience redundancy within the entire drinking water system; and
h) Controlling costs.

4.10.3 *Tactical Level Activities*

To avoid overloading of the information management process, the process of reviewing indicators to determine only productive and useful coherent information should consider as a major activity at the tactical level. The information should be manageable and relevant. Activities on a tactical level should include the following:

a) Analysing infrastructure asset life cycles;
b) Establishing operational information to be collected at the operational level;
c) Establishing a system for managing information;
d) Analysing reported information;
e) Analysing the value and performance of the assets;
f) Analysing of (specific) cost of planning, installation, operation, maintenance and rehabilitation;
g) Prioritizing infrastructure spending from available funds;
h) Maintaining an accurate asset data collection system;
j) Assessing the risks of asset failure or inability to meet the intended function;
k) Ensuring that the required maintenance is performed;
m) Controlling costs; and
n) Preselection of process and rehabilitation technology and materials.

4.10.4 *Operational Level Activities*

Activities on an operational level should include the following:

a) Collecting, monitoring and reporting asset operational information and condition;
b) Controlling costs;
c) Planning preventive maintenance schedules; and
d) Implementation of rehabilitation projects.

5 INVESTIGATION

5.1 General

Investigation should be carried out to assess the condition and the performance of the drinking water supply systems and their components. This may include:

a) identification of damaged, defective or incorrectly sized assets representing a potential hazard for utility services (volume, pressure, quality, no continual supply);
b) recoding of data about age, period of operation, maintenance intervals and history of disorder supporting the condition investigation and assessment;
c) the structure of the database should build on an asset labelling system, which assigns a unique identification to each important asset;
d) in addition to the assessment of the condition of assets, an investigation of the relevant processes should be done based on individual performance tests of functional groups, or on the whole drinking water system; and
e) results should be documented accordingly and backed up conveniently in a database to facilitate subsequent evaluations.

As the problems found in existing drinking water supply systems are frequently interrelated, the upgrading works should be designed to overcome a few problems at the same time, to the extent possible. The investigation and planning of rehabilitation work should be carried out on drinking water supply system so that all problems and their causes can be considered together. In large drinking water systems, it can be necessary to start by investigating appropriate parts of the system.

NOTE — The procedures described in this standard can be applied in any drinking water system, but detailed application should take account of the age, location and type of the drinking water supply system and the materials used in its construction, together with functional and climatic factors.

5.2 Purpose of Investigation

The investigation should be carried out to assess the performance of the drinking water supply system and its components. This should include the investigation aimed at tactical planning and operational planning.

The purpose of the investigation should influence the way in which it is carried out (choice of method, degree of detail, level of desired accuracy) and the way in which the results are assessed.

NOTE — The assets of the drinking water supply systems included in the investigation should be those that are necessary to fulfil the purpose of the investigation.

5.3 Determine the Scope of the Investigation

5.3.1 As per the review of the current performance information, the need of inspection should be decided whether to carry out an investigation or the extent of the problems justifies an investigation of all the facilities of a drinking water supply system. The extent and detail of the subsequent investigation of the hydraulic, process, environmental, structural and operational aspects should be determined.

5.3.2 Based on the technical expertise gained from these initial investigations the scope and format of future investigations should be defined. The investigations should be formalized as far as possible and conducted according to uniform criteria and evaluated to ensure the comparability of the results.

5.4 Data Collection

5.4.1 *General*

The drinking water utility should consider what data are important to acquire promptly and what further data should be acquired opportunistically to make data collection process cost effective. The drinking water utility should consider the purpose for which the data are to be gathered and design data recording methods to suit those needs.

Where there is insufficient information, the inventory should first be updated where required and any other information should then be collected during the hydraulic, process, environmental, structural and operational investigation.

5.4.2 *Data Requirements*

The quality of data should be assessed considering whether it is complete, compatible, consistent, current credible, accurate, and at a suitable scale.

5.4.3 *Inventory Data*

The drinking water utility should collect inventory data providing the essential technical information on the drinking water supply system and its components. Some examples of inventory data and the relevant components of drinking water supply system are provided in Table 2.

5.4.4 *Failure Data*

The drinking water utility should collect the failure data that provide information on failures found in drinking water supply systems and link this to inventory data. At the minimum, the following data should be collected:

a) Date of documentation, after final remedy;
b) Date of failure occurrence, if known;
c) Location (coordinates, address), point, type and cause (ageing, damage due to other construction, etc) of failure;
d) Type of remedy (repair, renovation, replacement);
e) Costs of eliminating failure; and
f) Consequence of failure (road collapse, leakage volume, number of customers without service).

For the determination and diagnosis of failures, uniform assessment criteria should be used and executed by well-trained personnel.

5.4.5 *Historical Data of the Assets*

The drinking water utility should acquire more information on the condition of drinking water supply systems as it provides valuable information on the prioritization of rehabilitation measures. The specifications and completion drawing of all assets should be retained by the managing authority for further assessment of assets during its life cycle. Data collection should be comprehensive, continuous and free from interpretation. Data registered should be uniform and based on previously and unambiguously defined default values. Free text should be avoided because it offers only limited evaluation possibilities. Where the inventory is incomplete, it should be updated so that a sufficient record of the network is available to carry out the investigation. Some examples of historical data and the relevant components of drinking water supply system are provided in Table 3.

Table 2 Types of Inventory Data
(*Clause* 5.4.3)
(*Informative*)

Sl No.	Inventory Data Attribute, if applicable	Assets				
		Facilities, Buildings and Structures	Mechanical Installations	Treatment Facilities/Processes (filters, sedimentation etc)	Piped Installation	Electrical/ Electronic Installation/ Equipment
(1)	(2)	(3)	(4)	(5)	(6)	(7)
i)	Location	X	X	X	X	X
ii)	Catchment area	X	X	X	X	X
iii)	Description of the functional specification of technical equipment and process technology	X	X	X	O	X
iv)	Type of asset (pump, filters, dosing facilities, provision and type of disinfection)	O	X	X	O	X
v)	Manufacturer of the relevant Equipment	O	X	X	O	X
vi)	Outdoor facilities such as access roads, plantings, fences, exterior design	X	O	O	O	O
vii)	Drainages	X	—	O	—	—
viii)	As built documentation of structures, equipment, schematics, drawings	X	X	X	X	X
ix)	Structural calculations (static and dynamic loadings)	X	O	O	O	—
x)	Building physics, structural design	X	—	O	—	—
xi)	Environmental conditions (soil conditions, contamination, groundwater, flood hazards, flood maps, power supply, sanitation, accessibility)	X	X	O	O	—
xii)	Year of installation	X	X	X	X	X
xiii)	Year of rehabilitation	X	X	X	X	X
xiv)	Type of rehabilitation	X	X	X	X	X
xv)	Year of decommissioning	X	X	X	X	X
xvi)	Installation/rehabilitation cost	X	X	X	X	X

NOTE — The list of inventory parameters can be modifying as per the requirements of drinking water utility.

Table 3 Examples of Historical Data

(*Clause* 5.4.5)
(*Informative*)

Sl No.	Inventory Data Attribute, if applicable	Assets				
		Facilities, Buildings and Structures	Mechanical Installations	Treatment Facilities/Processes (filters, sedimentation etc)	Piped Installation	Electrical/ Electronic Installation/ Equipment
(1)	(2)	(3)	(4)	(5)	(6)	(7)
i)	Performance of asset (pump, motor, switch etc)	X	X	X	X	X
ii)	Documentation of operating conditions	X	X	X	O	X
iii)	Maintenance and inspection documentation	X	X	X	X	X
iv)	Tightness of the structure	X	O	X	—	—
v)	Documentation of repair	X	X	X	X	X
vi)	Water tightness of the structure	X	O	O	O	—
vii)	Proof of stability	X	—	—	—	—
viii)	Energy efficiency	—	X	O	—	X
ix)	Corrosion/abrasion/cracks	X	X	X	X	X
x)	Environmental conditions (soil conditions, groundwater contamination, flood hazards, power supply, sanitation, accessibility)	X	X	O	O	—

NOTE — The list of historical parameters can be modifying as per the requirements of drinking water utility.

5.4.6 *Operational Data*

Operational data such as hours of operation of an asset, changes in flow rate or pressure should be acquired, as it provides valuable information on the facilities and components and on the prioritization of rehabilitation measures.

Supervisory Control and Data Acquisition (SCADA) systems can be designed to analyze the data (such as consumption patterns linked to the weather conditions, plots on pressures against flows, electrical energy consumption linked to consumer demands, record on system leaks, record on pump failures, areas with less chlorine residuals etc) and provide daily, weekly, monthly and or annual reports or schedules to monitoring the inventories on spare parts and plan requirement of spares. Responses for different scenarios such as seasonal changes or any emergencies should be programmed into SCADA to easily retrieved and analysed the information. Some examples of operational data and the relevant components of drinking water supply system are provided in Table 4.

NOTE — Manual on Operation and Maintenance of Water Supply Systems published by CPHEEO, Ministry of Housing and Urban Affairs on may be referred for further guidance on SCADA systems.

5.5 Data Registering and Data Assignment

5.5.1 *Data Registering*

The data to be registered as defined in **5.4** should be,

a) compiled, integrated, processed and safely stored and readily recoverable by the utility; and

b) checked and updated periodically or appropriately as they form the basis for developing maintenance plans and strategies.

Data collection can be performed using either mobile data collection devices or forms to be filled in manually (preferably box-ticking forms). It should be ensured that all data can be digitally aggregated in one place for a given drinking water supply system.

5.5.2 *Data Assignment*

All inventory, failure, historical, and operational data registered should be correctly assigned to the associated asset types such as electro-mechanical equipment, civil structures etc, and/or individual assets. Likewise, failure data (ageing, fatigue, damage caused by other processes or equipment, poor maintenance) should be assigned for maintenance/life cycle assessment.

5.5.3 *Georeferencing*

The inventory, failure, historical and operational data can be assigned to their associated objects through georeferencing for medium and short term rehabilitation planning to facilitate a rehabilitation strategy. The drinking water utility should avoid the practice of assigning data to particular asset system or material group instead of individual asset. Reference to individual assets as well as geo-referencing information should be preserved even when individual assets have ceased to form part of a currently existing network.

5.5.4 *Computerized Management Information System (CMIS)*

To make an effective CMIS, the drinking water utility should identify the potential sources of data in each functional area and create reports needed by all users irrespective of their proficiency in data processing. The reports for CMIS can be generated from following main/sub-systems of a drinking water utility:

a) Financial (payroll, revenue management, general ledger, accounting, funds etc);
b) Project management (engineering planning and design, construction, contracts and monitoring etc);
c) Human resource (manpower planning and recruitment, personnel development and training etc);
d) Material management (purchasing, inventory control);
e) Operation and maintenance; and
f) Marketing (customer information, demand forecasting, market planning etc).

5.5.5 *Review of Existing Information*

The collection and review of all available relevant information about the assets should be the basis of all other activities subsequently planned. A review should also be undertaken of the information required to manage the assets. This information should be assessed to determine what further information is required to carry out the investigation.

5.6 Types of Investigation

5.6.1 *Hydraulic Investigation*

An investigation of hydraulics should be made based on inventory data from the creation of the asset system and updated on the actual status. The interaction between pumping stations, treatment plants, storage reservoirs and the distribution network should be considered. In some cases, especially for larger assets, a simulation model may be required to understand the hydraulic system or the treatment plant by:

a) GIS based hydraulic model to understand the hydraulics of the system; and
b) GIS based hydraulic modelling for the designing of water network in urban areas.

The results of the hydraulic investigation can influence the operational and process management of the drinking water supply system and the interaction with other parts. These dependencies should be taken into consideration. Having identified possible causes of error it is often necessary to confirm these by site inspection and then adjust the model accordingly. Data should not be modified without justification based on an inspection of the drinking water supply system.

Table 4 Examples of Operational Data
(*Clause* 5.4.6)
(*Informative*)

Sl No.	Inventory Data Attribute, if applicable	Assets					
		Facilities, Buildings and Structures	Mechanical Installations	Treatment Facilities/ Processes (filters, sedimentation etc)	Piped Installation	Electrical/ Electronic Installation/ Equipment	SCADA/ Software/ IoT
(1)	(2)	(3)	(4)	(5)	(6)	(7)	(8)
i)	Hours of operation per day	O	X	X	O	—	X
ii)	Total hours of operation annually	O	X	X	O	—	X
iii)	Volume, flow	X	X	X	O	—	X
vi)	Pressure/water level	X	X	X	O	O	X
v)	Vibrations, sounds	O	X	X	—	X	—
vi)	Temperature of bearings/motors, pumps	—	X	O	—	O	—
vii)	Energy use of relevant equipment	O	X	X	O	X	X
viii)	Annual energy consumption	X	X	X	—	X	X
ix)	Energy costs (specific)	O	X	X	—	X	—
x)	Chemical use of relevant processes	O	O	X	X	—	X
xi)	Source water analysis	X	X	X	X	X	X
xii)	Water analysis at various treatment steps	X	—	X	—	—	X
xiii)	Drinking water analysis in distribution network	X	X	X	X	X	X

5.6.2 *Investigation of the Process Technique*

The entire process control system (including hardware and software) should be monitored regarding interfaces with other IoT systems or external communication links, and non-conformities investigated. It should establish the existence, or not, of a proper maintenance regime, a patch management process, a complete and current set of documentation and evidence of conformity with all IoT security requirements. The results of these studies and activities including subsequent change in the process control system should be documented.

5.6.3 *Structural Investigation*

The structural investigation should be undertaken when, during routine some deterioration on structural components of the relevant assets is found by visual inspection and/or the intended life of assets is about to end. The structural investigation can include either a complete survey of the structures of the drinking water supply system or a more selective approach investigations of wells, dams, storage reservoirs, filter basins and other buildings keeping in view of costs of rehabilitation versus investment in new facilities. Consideration should be given to the age and location of existing infrastructure, geotechnical data and the vulnerability of existing facilities. Where appropriate, other qualitative and quantitative investigation techniques may be used including laboratory analysis and field condition assessment to identify the integrity and remaining strength of a component.

5.6.4 *Operational Investigation*

5.6.4.1 For operational investigation, the drinking water utility should:

a) identify and document existing operational procedures, inspection schedules and maintenance plans;
b) review the frequency and location of recorded operational incidents such as loss of pressure, pumping station failures, process interruptions etc;
c) determine the impact of operational problems on the hydraulic and structural performance from incident records;
d) investigate the causes of significant recurrent operational incidents; and
e) investigate and understand the causes and effects of operational problems.

5.6.4.2 Operational investigations should be done to determine the following, but not limited to:

a) location of assets;
b) condition of assets;
c) cause and location of failures;
d) consumption of energy;
e) quality of construction or repair of structure and technical equipment; and
f) leakages.

5.6.4.3 Control system technologies like performance measurement, vibration measurement, efficiency determination etc, may be used to evaluate more complex causes of failures through trend analysis, and to assess interactions among the asset types. It applies to the interactions between drinking water supply system and between asset types within, and across, these systems. Operational investigation techniques can include:

a) diverse electronic sensors;
b) closed circuit television (CCTV) inspection of wells and pipelines;
c) flow and pressure measurement;
d) sampling and analysis; and
e) leakage control.

5.6.4.4 Irrespective of the strategy and the methods used, water infrastructure assets should be monitored periodically, and their components and operating equipment should be maintained and inspected regularly for their operating condition and functionality and in accordance with functional asset requirements.

5.6.4.5 A routine inspection of the condition of the service quality and particularly the asset ageing related conditions and the maintenance should start when commissioning water infrastructure assets. The designer and/or the owner or operator should specify the nature and frequency for the maintenance and inspection of the asset system or single assets. If historical data based on routine inspection are not available, all other available data based on historical assessment should be used.

5.6.4.6 A sufficient and reliable database on water infrastructure asset inventory and asset condition is indispensable for maintenance including strategy, planning and implementation. It is based on the qualified and quality assured collection, processing, evaluation and storage of asset-related data. All maintenance data, especially inspections, should therefore be recorded and documented.

5.6.4.7 Measurable condition data give decision makers the ability to see more clearly the consequences of their decisions and to avoid the many pitfalls that result from making funding decisions with an incomplete understanding of their infrastructure assets and needs. Operational problems concern the various components of drinking water supply system. The techniques available to resolve them are described in Annex B.

5.7 Inventory Update

Inventories should be updated periodically to maintain records of the drinking water supply system to carry out further investigations. At a minimum, each asset should be assigned a unique identification number. Formulating a hierarchical structure in the data is also helpful for information retrieval, analysis and reporting needs. Asset data attributes should be captured for each asset together with their source (design documents, information system). Mapping the data workflows among their sources and recipients can enable better functionality, efficiency and quality.

5.8 Review of Performance Information

5.8.1 Performance problems such as pipe bursts, leakages, loss of pressure and deterioration of drinking water quality can be known through reports of incidents, previous investigations or user's complaints. Records of past incidents and any other relevant information should be brought together, and a detailed review should be carried out to establish the scope of the investigations. Examples of such other information include:

a) hydraulic performance analysis,
b) performance of mechanical/electrical equipment, and
c) results of monitoring, performance and condition.

5.8.2 Where large numbers of treatment steps or the entire drinking water supply systems need investigation, the existing information collected may also be used to assign priorities to the investigation of the perceived problems in each service area (for example, by comparing the cost of the investigation with the benefit that might be achieved). These can then be used to draw up a comprehensive program with the intention to investigate facilities with the most serious projected problems.

5.9 Planning of Investigation

Target facilities and the execution period for medium-term survey plans should be decided according to the priority order based on risk assessment. The short term and medium-term plans should be based on the total work amount mentioned in the long term survey plan. The following should be evaluated for design of the survey work:

a) target facilities and period for inspection/survey;
b) determination of survey type;
c) survey method, item, standards; and
d) estimated cost.

5.10 Performance Testing

5.10.1 The performance of the drinking water supply system should test and assessed during construction, at the completion of the construction stage and also during the operational life of the system on a new asset, a long time existing asset or a rehabilitated asset. The examples of tests and assessments are:

a) leakage measurement;
b) visual inspection;
c) flow measurement;
d) hydraulic performance;
e) monitoring of equipment or process availability over the time in question; and
f) Water quality measurement, under different flow conditions, at treatment plant and at various treatment steps.

5.10.2 The effectiveness of maintenance should be assessed by comparing the performance of the system with its stated requirements. In addition, for reactive maintenance, target response times can be used as an assessment.

6 ASSESSMENT

6.1 Principles

Once the drinking water supply system has been inspected, the next stage is to examine the results to identify those areas requiring action. The performance of the system should be assessed against the performance requirements. The performance assessment should include the evaluation of risks of failure to achieve the performance requirements.

NOTE — Refer Fig. 3 for the process flow of assessment.

Results of Investigation

Assessment of the condition and deficiencies

Comparison with performance requirements

Identification of deficiencies

Identification of causes of performance deficiencies

Planning

FIG. 3 PROCESS OF ASSESSMENT

6.2 Assessment of the Hydraulic and Drinking Water Quality Performance

6.2.1 Based on the results of the investigation of the processes, the performance of the drinking water supply system should be assessed against the requirements for the maximum required power demand. This should consider peak hour, day and year requirements depending upon the design of the total supply (if necessary) and for the minimum necessary supply. The resilience for normal operation should be safeguarded by the necessary security and redundancy arrangements in accordance with risk management principles.

6.2.2 The results of the hydraulic and water quality surveys and/or the verified flow simulation model and the treatment process simulation model should be used to assess the hydraulic and water quality performance of the drinking water supply system related to the performance requirements for peak flow and, if appropriate, for firefighting conditions.

6.3 Assessment of Process Performance

The treatment and pumping process performance of a drinking water supply system should be monitored by both manual and/or online methods for determining the quantity and quality of raw and treated water. Deviations from the required performance should be evaluated and, after taking future requirements into consideration, can serve as a basis for improvement measures.

6.4 Assessment of the Structural Condition

Criteria such as serviceability, stability, protection of the escape routes, structure against environmental influences, natural calamities, fire, sabotage and protection against unauthorized access should be assessed to check the structural condition of drinking water supply system.

6.5 Assessment of Operational Performance

The operational performance of the system as measured by the number of operational incidents or failures should be assessed. This should be recorded in a database.

6.6 Compare with Performance Requirements

6.6.1 The results of the assessment of the hydraulic, procedural, structural and operational performance should be brought together so that the overall performance of the system and its components can be compared to the performance requirements as per **4.3**.

6.6.2 Performance indicators are one method of comparing the overall performance of a drinking water supply system with performance requirements and for comparing different treatment plants. They can be used as basic benchmarking purposes. Any performance indicators used should be,

a) clearly defined, concise and unambiguous;
b) verifiable; and
c) simple and easy to use.

6.7 Identification of Unacceptable Impacts

Details of those parts of the system where the hydraulic, procedural, structural or operational performance of drinking water supply systems its components does not meet the performance requirements should be recorded.

6.8 Identify Causes of Performance Deficiencies

Based upon the results of the hydraulic, procedural, structural and operational investigations, the causes of performance deficiencies should be determined. The relative impact of each cause should be assessed to develop appropriate solutions and to set the priority for action.

7 PLANNING

7.1 General

7.1.1 The integrated drinking water supply systems management plan can take one of two forms:

a) The plan describes the approach to be taken. An outline plan is likely to take this form, further information may be included in detailed plans for parts of the distribution; and
b) The plan outlines the proposed activities and measures and specifies the resources and timescales.

7.1.2 Planning may be categorized into strategic/long term plan (20 years to 30 years), tactic/medium term plans (8 years to 10 years) and operational/short term plan (upto 5 years).

NOTE — Refer Fig. 4 for the process of planning to fulfil the performance requirements.

Results of Assessment (*see* **6**)
→ Develop Integrated Solutions
→ Assess Feasibility of Solutions
→ Select Optimal Solution
→ Prepare Action Plan
→ Implementation (*see* **8**)
→ Monitoring and Review

FIG. 4 PROCESS OF PLANNING

7.2 Develop Integrated Solutions

Integrated solutions should be developed that fulfil the performance requirements, taking into account future conditions.

NOTE — Refer Table 5 for solution type and group for rehabilitation.

7.3 Assess Solutions

Solutions should be assessed, and the optimal solution should be selected based on the factors such as safety in construction and operation, social disruption, sustainable use of resources, phasing of work, relationship to other infrastructure works, capacity and resources constraints, future maintenance liabilities, economic appraisal and whole life cost.

7.3.1 *Safety in Construction and Operation*

Efforts should be made to minimize risks to health and safety during construction and subsequent operation of the system.

7.3.2 *Social Disruption*

The disruption to local residents and other members of the public due to traffic delays, dust, noise and other social factors should be considered.

7.3.3 *Sustainable use of Resources*

The use of energy and other finite resources in the construction and operation of the system should be taken into account. The ability to recycle materials used in the rehabilitation works and any waste produced should be considered.

7.3.4 *Phasing of the Works*

The possibility of integrating the solution into a staged program of works should be considered. This should consider the priorities of the works and the benefits in terms of improved performance associated with each identified phase of the works and the cost savings associated with deferral of the later stages.

7.3.5 *Relationship to other Infrastructure Works*

The benefits of phasing the works with other infrastructure works should be considered.

7.3.6 *Capacity and Resource Constraints*

Resource constraints (personnel, supply chain and financial) in the selection and phasing of the options should be considered.

7.3.7 *Future Maintenance Liabilities*

The cost of future maintenance works and other operational costs of the system should be considered.

7.3.8 *Economic Appraisal*

The costs and benefits should be considered to determine whether the additional benefits of one solution over another such as increased asset life, are justified.

7.3.9 *Whole Life Cost*

The whole life cost of a solution is the present value of all the costs over the life of the solution including temporary works and diversion of other utility services. All design, construction, investigation, maintenance and operational costs should be taken into account as well as the indirect costs (cost of social disruption and shifting of other services during maintenance). When comparing different options, the whole life cost should be calculated over the same period for each option.

7.4 Prepare Action Plan

7.4.1 The selected integrated solution should be documented to give a single plan for the drinking water supply systems. The documentation should include:

a) detailed objectives;
b) legal requirements and permits, including any timescales for rehabilitation;
c) performance criteria;
d) priorities;
e) proposed works including costs and phasing;
f) application of GIS in project planning, designing and maintenance;
g) relationship to other construction or planned development; and
h) consequences for operations and maintenance.

7.4.2 Four types of plans can be prepared:

a) New development plan;
b) Operations and maintenance plan;
c) Rehabilitation plan; and
d) Contingency and emergency plan.

8 IMPLEMENTATION

8.1 General

The implementation plan should take into consideration the financial risk(s) situation to the drinking water utility and can be based on the principle of ‘plan-do-check-act’ (PDCA) approach.

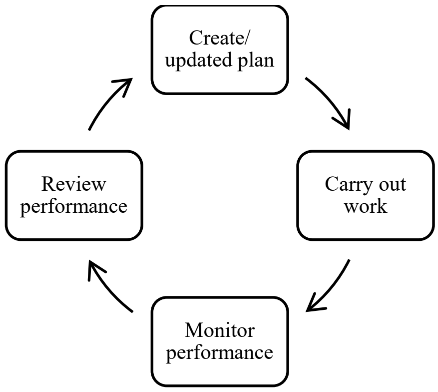


FIG. 5 PROCESS FOR IMPLEMENTATION FOLLOWING THE PDCA APPROACH

Table 5 Solution Types and Groups for Rehabilitation
(*Clause* 7.2)
(*Informative*)

Sl No. (1)	Type (2)	Group (3)
i)	Hydraulic	a) Maximize use of existing flow capacity. b) Adjust diameters and pipe wall friction to water demand and pressure. c) Increase the flow capacity by replacement of impellers of aged pumps. d) Target grid planning.
ii)	Structural	a) Protect fabric of mains by provision of appropriate linings or internal coatings. b) Achieve long term preservation of structure such as renovation of water storage facilities. c) Rehabilitate pipeline.
iii)	Operational	a) Undertake planned inspection and cleaning of facility. b) Optimize frequency of maintenance of equipment. c) Provide additional resilience in the event of future failure (provision of stand-by equipment or emergency storage).
iv)	Procedural	a) Adjust capacities and ensure effective assurance of water quality. b) Optimize energy use, improve efficiency, reduce CO_2 emission. c) Reallocate structures of drinking water system. d) Anticipate improvements necessary to meet future requirements. e) Optimize supply pressures, energy management, overall efficiency. f) Optimize the overall drinking water supply system including the influences of the catchment, upon the drinking water distribution network. g) Optimize planning for demographic and climate changes.

8.2 Create/Update Plan

8.2.1 The objectives and functional requirements, as well as the technical processes to investigate, assess and create maintenance, rehabilitation and operation plans, should be established to keep or improve the performance of the asset system. Necessary works to extend, reduce or rehabilitate any component or the entire drinking water supply systems as specified in the rehabilitation plan or the operational plan should be undertaken.

8.2.2 The implementation plan should be updated as necessary. This includes updating to identify a path forward enabling the drinking water utility to further improve its practices for management of assets to better attain its desired level of service while minimizing costs and effectively managing risk. If the performance requirements change, then the whole planning process should be repeated so that the entire plan remains up to date.

8.3 Carry Out Work

Where it is necessary to extend, reduce or rehabilitate any component or the entire drinking water supply systems, these works should be designed. The management of asset should include:

a) selection of appropriate technologies and materials;
b) selection of a constructor(s) appropriately experienced in use of the technologies and materials;
c) quality control of materials (specification and procurement);
d) quality of installation and conformity with installation requirements; and
e) evaluation of the process performance of each asset.

8.4 Monitor Performance

The drinking water utility should monitor the effectiveness of work undertaken and update the plan, including the records (inventory) and the GIS based hydraulic model or treatment process simulation model using performance indicator.

8.5 Review Performance

The performance requirements should be reviewed periodically.

9 OPERATION AND MAINTENANCE

9.1 General

To keep condition of the drinking water supply systems in the required status and providing the assets a long service life the drinking water utility should effectively operate and maintain the drinking water supply systems. GIS based operation and maintenance may be adopted to ensure that:

a) the entire system is operationally ready at all times and functions within the performance requirements;
b) the operation of the system is safe, environmentally acceptable, and economically efficient; and
c) as far as possible, the failure of one section of the drinking water supply systems does not adversely affect the performance of the other parts.

NOTE — Refer Table 6 for the relation between major terms of management of assets.

Table 6 Relation Between Major Terms of Management of Assets
(*Clause* 9.1)
(*Informative*)

Sl No.	Term	Retain Original Performance (routine activities)	Restore Original Performance	Upgrade GIS Based Performance	Examples
(1)	(2)	(3)	(4)	(5)	(6)
i)	Operation	Yes	No	No	Monitoring, regulation of flow, water quality, operation of pumps, valves, and treatment equipment, flushing filters.
ii)	Maintenance	Yes	Yes	No	Cleaning or flushing, filter, tanks, adjusting metering equipment, cleaning, local repair, replacement and/or lubrication of a pump or valve, replacement of electro-mechanical equipment or SCADA, repair of a pipe, pump or valve.
iii)	Rehabilitation	No	Yes	Yes	Relining of pipe; repair of a broken pipe, pump or valve; replacement orenlarging of an asset.

9.2 Operation

Urgent interventions that are generally intended to be temporary are included in operations. The drinking water utility should ensure that the drinking water supply system perform continuously and efficiently in accordance with its functional requirements and operational plan(s). Operation includes:

a) control of pumps, machine, and technical equipment;
b) monitoring and intervention to ensure that the processes of abstraction, catchment, treatment, pumping, storing and transportation are adequately delivered;
c) acting in accordance with contingency and emergency operation plans;
d) monitoring water quality;
e) control of non-revenue water (NRW);
f) optimization of water distribution network;
g) water audit and energy audit;
h) assessment of residual life of assets;
j) periodical inspection and documenting;
k) making connections to existing mains and to users;
m) check of building activities over or adjacent to water mains;
n) monitoring and controlling flow, pressure for continuous water supply; and
p) effective leakage management.

9.3 Maintenance

9.3.1 The drinking water utility should ensure that the drinking water supply system performs in accordance with its functional requirements and maintenance plan to ensure:

a) local repair or replacement of damaged pumps, motors, pipes, valves or other assets in order to maintain their functioning and safeguards;
b) cleaning, removal of sediments and disinfecting to restore hydraulic capacity and to ensure hygiene, water quality and performance restoration; and
c) regular attention to accessories like valves, dosing, control and metering equipment.

9.3.2 The drinking water utility should pursue a complementary balance of proactive maintenance with reactive maintenance to enable a more strategic approach that aims to achieve an optimal combination of cost and risk mitigation.

NOTE — Refer Table 7 for maintenance strategy.

Table 7 Overview of Maintenance Strategies
(*Clause* 9.3)
(*Informative*)

Sl No.	Maintenance Strategy	Brief Description	Advantage	Disadvantage
(1)	(2)	(3)	(4)	(5)
i)	Incident based	a) No action, to determine the actual status of the asset system. b) Only failure-based repair or replacement.	a) The service life of the asset is completely exploited. b) Low costs for inspection and documentation.	a) Unpredictable occurrence of failure. b) Consequential failures are possible, which leads to uneconomical repair. c) An incident or failure-based strategy can usually only be successful if the risk linked to the asset is low and will not be affected by an increased downtime and redundancy is sufficient.
ii)	Preventive	a) Few measures are taken for condition assessment. b) The preservation of the nominal condition of the assets is performed by preventative replacement of wear and tear parts.	a) Low unplanned failure probability. b) Predictable decommissioning.	a) High cost by low utilization of service life. b) High downtime caused by repair.

Table 7 (*Concluded*)

Sl No.	Maintenance Strategy	Brief Description	Advantage	Disadvantage
(1)	(2)	(3)	(4)	(5)
iii)	Asset condition based	a) If the condition of the asset is regularly identified by inspection, then the wear and tear is defined as the limit deviation in regard to the nominal performance. b) Risk-based maintenance is included.	a) Low unplanned failure probability. b) Predictable decommissioning. c) Optimal utilization of the service life.	a) Higher costs for the determination of condition. b) Higher qualification of the staff.
iv)	Predictive	Besides the determination of the condition, it is also intended to improve the asset and to reduce the wear and tear.	a) The availability of the complete asset system increases. b) Long term, the expenses for maintenance decrease.	a) High costs for troubleshooting. b) Very high qualification for the staff.

10 REHABILITATION

10.1 General

10.1.1 Rehabilitation should take into consideration all aspects of selection, installation, maintenance, repair, renovation, replacement and decommissioning to fulfil the objectives.

10.1.2 Once a drinking water supply system is installed and operated, the highest expenditure in costs over the life cycle should be determined by consumption of resources which includes energy, dosing agents, disposal of residuals, and personnel expenses for operation and maintenance plus decisions on rehabilitation of these resource.

10.1.3 The rehabilitation of assets or parts of the asset system should be adopted if the cost of maintenance and operation of the facilities increases beyond what is reasonable, or the quality of the source water or the legal requirements for drinking water change or in case of damage to the structure.

10.1.4 A sustainable process for managing water assets can be subdivided into the following three logical steps that build upon each other to be able to identify and assess (including by way of comparison) the short, medium and long term impact of rehabilitation:

a) Determining a long term rehabilitation strategy;
b) Drafting a medium term rehabilitation tactic; and
c) Implementing operational rehabilitation measures required in the short term.

10.1.5 The strategy for rehabilitation should be determined by identifying the scope of rehabilitation works required and the pertinent budget based on a long term perspective to obtain and/or maintain adequate system condition and resulting levels of service.

10.1.6 The key objectives of the rehabilitation of drinking water supply systems consist of:

a) minimizing interruptions of service in any situation;
b) retaining the necessary water quality (relevant water quality parameters);
c) avoiding hazards to humans, third party assets and the environment;
d) improving or maintaining the level of service; and
e) achieving the lowest possible total expenditure.

The extent to which achievement of each of these objectives can be influenced is indicated in Table 8.

10.2 Strategic Plan for Rehabilitation of Assets (long term planning)

10.2.1 *General*

10.2.1.1 The development of the rehabilitation strategy for a long term period should focus the scope of rehabilitation measures, the rehabilitation budgets required to achieve and to maintain sufficient service quality and facility condition levels.

10.2.1.2 The extent of the rehabilitation work required should be determined based on homogenous asset types exhibiting identical or similar condition developments/ageing behaviours, whose condition developments and/or service lives are expected to be statistically comparable.

NOTES

1 As an example, subdividing the drinking water supply system into the following major asset types:

a) water catchment infrastructures, including wells and related technical equipment;
b) intake assets;
c) water source such as aquifers, impounding reservoirs, borehole, river, surface water;
d) pumping stations;
e) disinfection equipment;
f) tanks and filters for various treatment steps;
g) supply reservoirs and other structures;
h) chemical dosing and monitoring equipment;
j) control and automation systems;
k) drinking water distribution network (trunk mains; primary, secondary and tertiary mains; and service pipes for house service connections); and
m) other installations such as electrical and mechanical equipment.

2 Depending on the available data and following an analysis of the existing system, the similar type assets within major asset types may further broken down, based on:

a) data transmission and supervision systems;
b) metering technology; emergency power systems;
c) buildings, properties, fences, supervision systems, security systems;
d) asset types of comparable location and installation conditions; and
e) asset types of comparable modes of operation and/or conditions of use.

10.2.1.3 Single unit in function groups should be combined and then undergo a joint rehabilitation of the whole functional unit largely to take advantage of a corresponding improvement potential.

10.2.1.4 Certain areas or asset types exhibiting unusual or above-average water leakage or exceptional underperformance and quality problems or exceptional high cost and frequent disorder that have a major impact on the rehabilitation strategy should be broken down accordingly into asset sub-groups with advance differentiation.

10.2.1.5 The rehabilitation strategy should be defined at a point in time that permits identifying and responding appropriately to the probable long-term need for rehabilitation. A period of review of 30 years to 50 years should be taken, depending upon the materials, to completely cover the relevant condition developments of the asset system or types to be rehabilitated. Function, condition of installation and operation of each asset type should be considered in setting the review period.

10.2.1.6 The rehabilitation strategy varies between different asset types depending on maintenance strategy and risk assessment. Rehabilitation of small assets such as fittings and service pipes should be event oriented, whereas for large assets such as service mains, rehabilitation can be condition oriented.

10.2.2 A*pproach for Strategic Plan*

Several rehabilitation approaches are possible for the formulation of the strategic plan depending on local conditions, technical advancement, eco-friendly cost effective and the risk attached to consequences. The statistical estimation can be used to understand rehabilitation needs if deterioration due to ageing was recognized during inspection. Possible approaches include:

a) *Asset value approach* — A financial-based approach should be carried out to ensure that rehabilitation does not compromises the value of the drinking water supply systems below a specified threshold at the end of specified period;
b) *Asset-type approach* — A part of the assets of a drinking water supply system should be selected with common characteristics, requirements and properties such as a treatment step, a well field or a monitoring system;
c) *Asset condition approach* — All components of a drinking water supply system should be inspected and those that do not meet some specified threshold conditions are rehabilitated. If all components of a drinking water supply system cannot be inspected in a short period, a sampling survey and a screening method can be used;
d) *Functional-related approach* — This should be built around the need for changes to improve the performance of the drinking water supply system including the need to reduce or eliminate constituents of the source water and takes the opportunity to do other rehabilitation work where this can be done more efficiently at the same time;
e) *Reactive approach* — This should involve responding to failures and problems as they are identified; and
f) *Risk-based approach* — The risks arising from or affecting water infrastructure assets should be well known to attain the rehabilitation objectives.

The reactive rehabilitation approach should only be used where the risk of failure is considered, considering both the probability of failure and the consequences. The advantages and disadvantages of above listed strategic approaches are listed in Table 9.

10.2.2 *Determination of Rehabilitation Rate Based on Service Life*

The reciprocal of the technical service life or expected service lives or the residual service lives (if little or no rehabilitation measures have been taken so far) of the asset types concerned can be used as a first approximation for determining the required annual rehabilitation rate. This is true particularly for asset type that have grown homogenously over a long period of time, and for which no reliable data are available on age-related length distributions within the asset types.

10.2.2.1 The service life of asset types can be estimated based on:

a) empirical data and historical rehabilitation statistics of the utility;
b) measurements in connection with investigations or assessment of condition;
c) evaluation of statistics of failures or disorders;
d) increasing amounts of maintenance;
e) special investigations; and
f) other sources, such as technical literature, exchanges of technical information.

NOTES

1 Information in the technical literature should be critically compared with empirical data from the drinking water utility's direct experience.

2 The estimation of the remaining service life for each asset type should be verified by failure analysis and compared with the age-related development of failures if available.

3 Failures of assets already out of operation should also be included.

10.2.2.2 Maintenance and rehabilitation of machinery or asset types should ensure correct functioning of assets to reach their technical service life. The maintenance strategy should be adapted specifically according to the requirements of safety efficiency.

10.2.3 *Determination of Rehabilitation Rate Based on Mathematical Distribution Function*

By employing mathematical distribution functions (Gaussian, Weibull, Herz distribution), the probable point of transition into the projected poor condition (the end of the service life) can be calculated. This method ultimately provides a more meaningful picture of required, long-term annual rehabilitation rates.

For this method, the drinking water utility should consider actual operating service lives of individual assets within an asset type which vary within certain boundaries, depending on the factors affecting the system's condition.

If a correspondingly detailed data collection and analysis are available, the preferred method should be Method 3, with a view to enhancing economic efficiency and planning safety.

NOTES

1 Failure data, common operation usage and age of relevant assets are required for methodologically correct analysis in a rehabilitation strategy context.

2 Established trend or regression functions can be employed to describe the calculated age-related progression of failures, to determine the service life and to forecast failure rate development. If necessary, experts should be consulted for failure statistics analysis.

3 Commercially available software products and the corresponding necessary data are available and may be employed to calculate service life margins and derive from this basis one or more of the above mentioned probability distributions.

10.2.4 *Budgeting*

10.2.4.1 The rehabilitation budget required to implement a rehabilitation strategy can be determined by the product of the annual rehabilitation rates and the respective asset lengths and numbers and the specific cost estimates while considering:

a) cost estimates based on utility-specific, long-term empirical data, as well as on any planned changes in materials and systems; and
b) inclusion of results of possible strategic optimization activities in the rehabilitation budget calculation.

10.2.4.2 Since a rehabilitation budget calculated in accordance with the method described above only covers the condition based rehabilitation of a drinking water supply system, expenditures on third party induced replacement (in the absence of an urgent need for rehabilitation) should be added to the rehabilitation strategy budget.

10.2.4.3 Regular maintenance should be adopted to extend the service life of assets or asset system to reduces life cycle cost.

Table 8 Rehabilitation Objectives
(*Clause* 10.1.6)
(*Informative*)

Sl No.	Rehabilitation Objectives		Strategic Plan	Tactic Plan	Operational Plan
(1)	(2)		(3)	(4)	(5)
i)	Minimising asset failures and service interruptions	Complete asset system	X	X	—
		Asset type	X	X	—
		Asset	—	X	X
ii)	Keeping required drinking water quality		X	X	X
iii)	Reducing water leakages or keeping them at low levels		O	X	X
iv)	Resource reliability		X	X	X
v)	Avoiding hazards to humans, third party assets and the environment		—	X	X
vi)	Improving or maintaining level of service	Pressure and quantity	—	X	X
		Water quality	O	X	X
		Availability	X	X	X
vii)	Minimising the required total cost of maintenance while keeping up the necessary service standard		X	X	X

NOTE — To achieve the objectives linked to the rehabilitation measures, good knowledge of the risks affecting the water infrastructure assets should exist. For more details of likelihood and impact of failures or incidents (*see* **10.3**).

Table 9 Advantages and Disadvantages of Different Strategic Approaches
(*Clause* 10.2.2)
(*Informative*)

Sl No.	Approach	Advantages	Disadvantages
(1)	(2)	(3)	(4)
i)	Asset-value	a) the changes in asset value of the drinking water supply system can be made transparent. b) suitable for determining a fixed-rate budget.	a) it is financially driven. b) It can't be used solely but can be used in combination with other approaches.
ii)	Asset-type-related	a) it is easy to get a clearer view of the work and the benefits. b) it is possible to carry out the work in a defined period. c) amount of work in one area can be financially efficient.	a) a detailed cost estimate can only be made after detailed investigation of the area. b) influence of other asset type is not included in this approach.
iii)	Asset condition based	a) status of structures, equipment and function are known by inspection b) reduction in need for reactive rehabilitation. c) very efficient way of rehabilitation by selecting only assets with high priority. d) the complete drinking water supply system is maintained to a defined standard.	a) problems with a lower priority remain in the drinking water supply system for a longer period. b) loss of efficiency by the possible need to carry out further works in the same parts of the drinking water supply system later.
iv)	Functional related	future oriented planning creates capacity, alleviating problems before they occur.	cannot be applied as sole approach.
v)	Reactive	can be cost effective where consequence of failure is low.	a) cannot prevent failures occurring. b) can only be safely based on a risk based approach.
vi)	Risk based	optimal risk − cost ratio, bundling of works to optimize time and manpower costs.	can lead to compromised water quality, breakdowns or service interruptions.

10.2.4.4 Spreads the levels of the rehabilitation cost across the years to an extent balanced with strategic proactive capital improvements.

10.2.4.5 The future plan for rehabilitation work for the assets or asset system should be estimated.

10.3 Tactical Plan for Rehabilitation of Assets (mid-term planning)

The tactical rehabilitation plan pursues the objective of implementing in the medium term, (8 years to 10 years), and the amount of rehabilitation determined by the rehabilitation strategy for the individual asset types. The operational rehabilitation measures required for the task should be identified and prioritized.

10.3.1 *Risk Based Approach to Evaluate Priority*

The criteria for prioritization should be based on the risk emanating from an asset or affecting its function. This risk results from the probability of occurrence and the consequence of failure. Health risks are of particular importance for all stakeholders. The drinking water utility should consider the risk of:

a) deficiencies in the level of service (quantity, pressure, drinking water quality);
b) direct added costs;
c) the resultant negative public perception of a failure; and
d) its image.

The probability and the extent to which drinking water quality is affected can be derived from customer complaints, operating experience and measured values.

10.3.2 *Risk Assessment*

The risk assessment process should require establishment of risk analysis criteria for a risk event's likelihood (probability) of failure or occurrence and its potential impact (extent of failure or disorder). The drinking water utility should define utility-specific risk-assessment criteria that support a risk evaluation approach capable of producing risk evaluation results for each facility. Risk assessment criteria can be subdivided into the following groups:

a) The probability of failure occurrence based on:
    1) the failure rate development in a component (individual or in aggregate);
    2) the failure rate development in the asset type (failure and/or empirical data);
    3) condition data of machinery and technical facilities (corrosion, cavitation, efficiency, connection type, coating);
    4) ambient data (bedding, soil corrosiveness, stray currents, traffic load, overbuilding); and
    5) knowledge about fluctuating level of service.
b) The probability of occurrence of impairments based on operational experience, measured values and calculations, and customer complaints; and
c) The extent of failure or disorder in relation to cost, hazards to persons, assets (tangible and intangible), and environment and drinking water utility's image/public perception.

10.3.3 *Decision Making*

10.3.3.1 A risk assessment process should be defined and documented that contains the relevant criteria for the relative evaluation of the risks. Application of the process will produce data. The process should determine how the risk assessment should be applied to assets and asset types with both similar and dissimilar characteristics.

10.3.3.2 Each criterion should be applied to asset types of equal technical characteristic. The final overall evaluation can be attained by comparing the individual evaluation results. As this step constitutes the most crucial procedure in the process, it should be prepared and coordinated with due care. The combination of the individual evaluations should correctly reflect the weighting of the criteria against each other within the same asset type and across similar asset types. Sorting the evaluation results and yielding the competing priority ranking of the rehabilitation measures should be planned for the medium term.

10.3.3.3 When selecting evaluation criteria, care should be taken to ensure that information about each criterion is available for each component or else the evaluation results can be distorted. The source and reliability of the information should be evaluation process. The absence of information should not be a reason for excluding a risk from the evaluation process.

10.3.3.4 The list of competing priorities emerging from the evaluation of risks should provide the following information about the individual assets or asset types as a minimum requirement:

a) Unambiguous identification of a component (technical data); and

b) Quantitative evaluation (how many points have been scored).

10.3.3.5 The list of competing priorities should be compared with the pre-determined strategic rehabilitation objectives (attaining a certain level of rehabilitation). The list of competing priorities should be processed in accordance with the rehabilitation strategy. Any deviations from the list of competing priorities in the rehabilitation strategy should be evaluated and examined for their relevance to impacts on the rehabilitation strategy.

NOTE — A decision on the competing priorities can be aided using a risk scoring classification system (*see* Annex B).

10.3.4 *Risk Control*

Subsequent to identified, described, identification, description and analysed each risk using a consistent set of risk analysis criteria, a drinking water utility should evaluate the relative significance of each risk compared with the others based on a consistent set of evaluation criteria. The evaluation results for the entire drinking water supply system or for individual components should determine the rehabilitation priority ranking of the assets concerned. Risk can be expressed by a variety of units.

NOTES

1 For rehabilitation strategy, the aspect of risk can be considered to a limited extent as the technical evaluation of rehabilitation strategy can only analyse and predict the asset type-related failure probability.

2 If failures can be clearly attributed to individual asset types and not to individual components, these aspects, too, can be considered in the rehabilitation strategy.

3 All requirements should be completely fulfilled and cannot be offset one against another as even low failure rates imply a poor quality of drinking water supply and high-water losses.

4 In rehabilitation planning and execution of rehabilitation measures, all influencing risk factors can be evaluated by reference to the location of the individual assets.

5 Fig. 6 illustrates the risk-assessment process leading to the evaluation of assets' priority for rehabilitation.

10.4 Operational Plan — Implementation of Rehabilitation Measures (short term planning)

10.4.1 Shorter periods of review require more intense work and higher degrees of detailing of the respective sub-processes, entailing a higher total expenditure in terms of both time and cost. Therefore, the drinking water utility should collect more precise details of the functioning of the assets.

10.4.2 The short term rehabilitation measures should be designed and implemented considering prevailing local conditions.

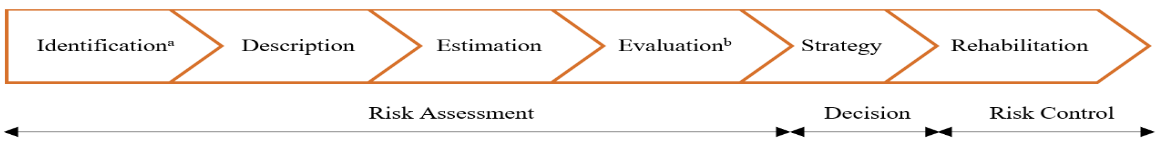
10.4.3 Alternative construction technologies should be considered when planning the construction measures. Simultaneously rehabilitate adjacent sections of roughly the same priority ranking to achieve economies in the rehabilitation program such as energy efficiency, reduction of chemical use or reduction of other operating costs.

10.4.4 Construction measures such as dimensions, rehabilitation technology and the rehabilitation materials should be defined for the individual asset. This should also include quality assurance of materials and installation, as well as requirements for the executing contractors.

NOTE — Guidance may also be taken from Operation and Maintenance of Water Supply Systems published by CPHEEO, Ministry of Housing and Urban Affairs, for the preparation of operation and maintenance plan.

11 DOCUMENTATION AND EFFICIENCY REVIEW

11.1 All major results and decisions should be documented to be able to understand the individual process steps, from the original strategic approach to the final execution of the work. Care should be taken in this context to include previous experience with such measures and apply it to planning future work. The documentation should be safely filed, publicized and made accessible.



a: Identification of each risk individually;

b: Evaluation of all risk relative to one another.

FIG. 6 PROCESS OF RISK ASSESSMENT, DECISION MAKING AND RISK CONTROL

11.2 To the extent necessary, the drinking water utility should ensure the annual appraisal of the following records:

a) Operation of its processes;
b) Workforce employed and needed, as per schedule; and
c) Traceability of water/processes causing major/minor non-conformity.

11.3 Awareness can be created among the drinking water utility about the importance of upkeeps of records. The foremost reason for such situation is the lack of reliable records, in the absence of which one may be forced to take decisions purely on guess work instead of taking decisions based on reliable records.

11.4 Efficiency reviews should be carried out at regular intervals including all persons involved in the respective processes to be able to adapt the rehabilitation strategy and plan. The following questions should be addressed during efficiency review:

a) Have the rehabilitation objectives been reached;
b) Have the budget constraints been observed;
c) Were the rehabilitation techniques and materials adequate or were there better solutions;
d) Is there a need to modify any evaluation criteria and/or standards;
e) Was the cost per service or capital spent target achieved;
f) Were the infrastructure asset condition indicators accurate and useful;
g) Do the indicators need to be adjusted; and
h) Were the rehabilitation works carried out without negative impact on the network users or the environment.

In all cases, if the assessment is negative, then the question 'Why not', if applicable, should be answered.

11.5 The efficiency review should be documented clearly and made accessible to the decision makers.

11.6 The rehabilitation strategy in place should be reviewed periodically and modified, if necessary.

11.7 The current rehabilitation plan should be reviewed based on the performance monitoring reports, and no less frequently than once per year, and modified if necessary.

ANNEX A

(*Clause* 4.1)

(*Informative*)

FURTHER OBJECTIVES OF THE MANAGEMENT OF ASSETS OF DRINKING WATER SUPPLY SYSTEM

A-1 Reasons for the management of assets of drinking water supply systems include:

a) drinking water supply systems are exposed to risk-carrying internal and external interferences impacting water quality and security of supply;
b) continuous drinking water supply are designed to have long service lives;
c) the absence of maintenance can endanger the reputation of and confidence in the drinking water utility by causing serious deviations from water quality and security of service standards, resulting in serious damage to third parties;
d) the user has a right to demand a service that provide of safe drinking water; and
e) service interruptions should be kept to a minimum.

A-2 The management of assets of drinking water supply systems should consider the following operational and maintenance objectives:

a) Minimizing environmental impairment;
b) Causing no detrimental impact to public health;
c) Avoidance of water quality impairments;
d) Reducing water losses or keeping them low;
e) Stabilizing the pressure level;
f) Keeping supply interruptions, especially those caused by equipment failure (number and duration per user), to a minimum;
g) Correcting failures and defects within a reasonable period;
h) Optimizing the service life of existing systems, while simultaneously maintaining service quality;
j) Maintaining and improving user satisfaction;
k) Optimizing maintenance costs, while maintaining the required level of service;
m) Conserving the existing structure of and safeguarding of the quality of the drinking water supply system;
n) Use chemical agents rationally; and
p) Ensuring the environmental compatibility of all measures and activities.

A-3 The overall objective of the management of assets should be to ensure that the drinking water utility complies with its service mandate while also maintaining a stable economic position.

ANNEX B
(*Clauses* 5.6.4.7, 10.3.3.5)
(*Informative*)

RISK BASED ASSESSMENT FOR REHABILITATION

B-1 The provisions set forth in this guideline are intended to help attain operation and maintenance objectives and prevent any negative consequences caused by potential hazards to the security of supply (quantity, pressure and quality).

B-2 IDENTIFICATION OF HAZARD

Potential hazards can be caused by:

a) incorrect dimensioning of equipment;
b) inappropriate choice of materials and components;
c) unsuitable or faulty design or construction method;
d) incorrect repair or maintenance measures having contact with drinking water;
e) poor commissioning/decommissioning activities;
f) operating with critical flow conditions (flushing);
g) poor disinfection or secondary disinfection in the pipeline network;
h) inadequate rehabilitation practices;
j) unsafe treatment concepts;
k) unsafe distribution concepts;
m) functional faults and failure of systems and components;
n) unacceptable water pressures;
p) poor system operational management and/or security controls;
q) impairment caused by environmental factors;
r) poor third-party construction work;
s) insufficient numbers or qualification of staff;
t) inadequate plant management;
u) stagnant water;
v) poor storage of components;
w) infiltration or feeding of non-potable water;
x) high water losses; and
y) frequent failures.

The hazards resulting from the issues listed above can form the basis for further risk assessment.

B-3 ESTIMATION OF LIKELIHOOD

The likelihood of failure occurrence can be set by following methods according to the collected data:

B-3.1 Asset Failure Likelihood Estimation by Age

A preliminary estimation of asset types with a higher likelihood of failure can be made by an assessment of asset age. For example, by assigning the following weighting scores:

a) 4 — Elapsed years of 30 or more to less than 50;
b) 3 — Elapsed years of 15 or more to less than 30;
c) 2 — Elapsed years of 5 or more to less than 15; and
d) 1 — Elapsed years of less than 5.

B-3.2 Operation and Maintenance Information

To analyze the facilities and/or areas with high possibility of failure by interviewing personnel with operation and maintenance experience, consulting the operation and maintenance data (data concerning facility conditions obtained by inspection and repair), consulting data concerning users' complaints, including low water quality, low pressure, service interruption, classified by area and facility that can be used to estimate likelihood.

B-3.3 Local Environment

Likelihood of failure should be estimated based on pre-determined characteristics consistently applied, for example:

a) assets under peculiar local conditions and environment;
b) pipe and pumps operated under an unusual pressure regime;
c) areas where complaints and/or unusual cases including low water quality, chlorine taste, chemical and/or microbiological findings; and
d) component conditions such as material, bearing temperature, vibrations, failure frequency.

ANNEX C
(*Foreword*)

COMMITTEE COMPOSITION

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Panel for drafting standard on Distribution Network and Vocabulary, SSD 14/Panel 3

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Amend No.	Date of Issue	Text Affected

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