INTERNATIONAL STANDARD

ISO 24516-4

First edition
2019-04

Guidelines for the management of assets of water supply and wastewater systems —

Part 4: Wastewater treatment plants, sludge treatment facilities, pumping stations, retention and detention facilities

Lignes directrices pour la gestion d'actifs des systèmes d'eau potable et d'eaux usées —

Partie 4: Stations d'épuration des eaux usées, installations de traitement des boues, stations de pompage, installations de rétention et de retenue

Reference number
ISO 24516-4:2019(E)

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Published in Switzerland

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Foreword

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The procedures used to develop this document and those intended for its further maintenance are described in the ISO/IEC Directives, Part 1. In particular, the different approval criteria needed for the different types of ISO documents should be noted. This document was drafted in accordance with the editorial rules of the ISO/IEC Directives, Part 2 (see www.iso.org/directives).

Attention is drawn to the possibility that some of the elements of this document may be the subject of patent rights. ISO shall not be held responsible for identifying any or all such patent rights. Details of any patent rights identified during the development of the document will be in the Introduction and/or on the ISO list of patent declarations received (see www.iso.org/patents).

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For an explanation of the voluntary nature of standards, the meaning of ISO specific terms and expressions related to conformity assessment, as well as information about ISO's adherence to the World Trade Organization (WTO) principles in the Technical Barriers to Trade (TBT) see www.iso.org/iso/foreword.html.

This document was prepared by Technical Committee ISO/TC 224, *Service activities relating to drinking water supply, wastewater and stormwater systems*.

A list of all parts in the ISO 24516 series can be found on the ISO website.

Any feedback or questions on this document should be directed to the user’s national standards body. A complete listing of these bodies can be found at www.iso.org/members.html.

Introduction

This document is written within the overall concept of management of assets, which is an activity all organizations undertake in some manner and to some degree. It focuses on the details of managing the physical assets at the operational level rather than the organizational (corporate management, structure or process) level.

Wastewater utilities are reliant on their assets to deliver their services to the users in their service areas. The assets (e.g. underground pipes, retention and detention tanks and treatment plants) collectively form the physical infrastructure of the wastewater utilities and are the consequence of the accumulated capital investments and operational expenditures on maintenance and rehabilitation over many years. In many of these utilities, the replacement value of these past investments will amount to many millions (even billions) of US dollars depending on the size of the community served. The infrastructure represents a major societal investment in essential services contributing to public health and the protection of the environment.

In many countries, these assets have been identified as critical infrastructure and programs are in place to ensure their protection or their sustainability. Like many other organisations with assets, wastewater utilities undertake programs of activities to manage the assets to ensure they continue to meet the needs of the community. These management activities can be at the strategic, tactical or operational level. The activities can be part of a formal management system, or the result of specific legislative requirements, or simply the result of due diligence by the service operators and managers.

This document can serve as a supporting document for utilities operating an asset management system regardless of whether or not the utilities make use of any management system standard, for example ISO 55001.

In many countries, there is a recognized sustainability problem, sometimes referred to as the infrastructure gap, which recognizes that, for various reasons, the infrastructure has not been maintained over the years on a truly sustainable basis, i.e. funding and implementation of rehabilitation programs have been postponed, with a focus instead on short-term repairs, or an allowed decrease in the level of service provided.

The condition of wastewater infrastructures greatly influences the adequacy of the wastewater service from the aspects of quality, quantity, safety, reliability, environmental impact, sustainability, the degree of treatment and efficiency. System condition-based rehabilitation approaches serve to meet these requirements with a focus on a holistic approach of condition-based, risk-oriented maintenance.

As the installation and development of wastewater assets matures, the optimization of the wastewater infrastructure will become necessary in many places in order to compensate for ageing and wear and tear and to respond to changing societal and economic conditions. Consequently, wastewater infrastructure assets are subject not only to ageing and wear and tear but also to adaptation processes resulting from growth, new legislative requirements, technical innovations or changing user-service-level expectations. This requires wastewater utilities not only to focus on maintenance and rehabilitation but also to keep future requirements and developments in mind. Rehabilitation will thus become essential in management of assets, with ever more stringent requirements on the design and execution of rehabilitation.

In recent years, much effort has been applied to the whole issue of management of assets on two levels:

— What are the principles and structure of an asset management system?

— What are the good practices that can be implemented on a technical level to assess the condition of the assets and help decide when asset interventions (repair, renovation or replacement) should take place?

This document describes the information required and how to collect and process reliable inventory, condition, operational and context data about technical assets of wastewater systems, including failures. These data should serve as the basis for a systematic management of assets and can also contribute data needed for benchmarking purposes. 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 for establishing a risk-based investigation to determine maintenance and rehabilitation.

This document also provides guidance on how to define a strategy for management of assets with regard to the overall performance expected by the owner and other stakeholders. It includes several aspects of operation and maintenance, including asset condition assessment and investment strategies (new assets and rehabilitation).

The approaches offered in this document are intended to be universally applicable, regardless of the structure of a given wastewater system. Any empirical numeric values given are mere support values; concrete plans should always rely on utility and/or object-specific values.

The usual and expected goal of the effective management of assets is to provide maximum life and value in a cost-effective manner. However, in some circumstances where the assets are being operated to satisfy a short-term goal, this will not be to maximize the life of the assets, but could, for example, be to minimize costs while meeting other objectives within the planned timeframe.

Additional information on objectives and functional requirements of management of assets is provided in Annex A; an example of the content of a wastewater master plan is provided in Annex B; and examples of inventory, condition and operational data are provided in Annex C. Methods for the risk-based assessment for rehabilitation are shown in Annex D.

Guidelines for the management of assets of water supply and wastewater systems —

Part 4: Wastewater treatment plants, sludge treatment facilities, pumping stations, retention and detention facilities

1 Scope

This document specifies guidelines for technical aspects, tools and good practices for the management of assets of wastewater treatment plants, sludge treatment facilities, pumping stations, and retention and detention facilities in the wastewater system to maintain the value of existing assets.

NOTE 1 For simplicity in reading this document, reference to wastewater treatment plants includes all the asset types described above.

For further guidance on wastewater networks see ISO 24516-3.

NOTE 2 For simplicity of interpretation of wastewater system assets, the management of pumping stations and retention and detention facilities in the network, excluded from ISO 24516-3, is addressed in this document irrespective of where these assets are sited in the wastewater system.

This document is focused on the assets in wastewater systems typically owned or operated by wastewater utilities that are expected to meet users' needs and expectations over longer, sometimes multi-generational, periods.

This document includes examples of good practice approaches on the strategic, tactical and operational levels.

This document is applicable to all types and sizes of organizations and/or utilities operating wastewater systems.

NOTE 3 Depending on the size and structure of an organization, the utility can decide to what extent it applies the guidance in this document. In any case, the philosophy of this document remains applicable even to small and medium utilities.

NOTE 4 This includes all different roles/functions for the management of assets within a utility (e.g. asset owner/responsible body, asset manager/operator, service provider/operator).

2 Normative references

There are no normative references in this document.

3 Terms and definitions

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

ISO and IEC maintain terminological databases for use in standardization at the following addresses:

— ISO Online browsing platform: available at https://www.iso.org/obp

— IEC Electropedia: available at http://www.electropedia.org/

3.1
asset
item, thing or entity that has potential or actual value to a water utility

Note 1 to entry: Assets are used in a water utility for the provision of the *service* (3.20).

Note 2 to entry: 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.

Note 3 to entry: Physical assets usually refer to equipment, inventory and properties. Examples in the water sector are land, buildings, pipes, tanks, treatment plants, equipment and hardware. Physical assets are the opposite of intangible assets, which are non-physical assets such as leases, brands, digital assets, use rights, licences, intellectual property rights, reputation or agreements. Examples in the water sector are water rights, software and databases.

Note 4 to entry: A grouping of assets referred to as an *asset system* (3.2) could also be considered as an asset.

[SOURCE: ISO 24513:2019, 3.6.1]

3.2
asset system
set of *assets* (3.1) that interact or are interrelated

[SOURCE: ISO 24513:2019, 3.5.12]

3.3
asset type
grouping of *assets* (3.1) having common characteristics that distinguish those assets as a group or class

Note 1 to entry: Examples of asset types include, but are not limited to, physical *assets* (3.1), information assets, intangible assets, critical assets, enabling assets, linear assets, information and communications technology (ICT) assets, infrastructure assets and moveable assets.

Note 2 to entry: Examples of physical asset types in the water sector are pipes, valves, pumping stations and reservoirs/tanks of the same type, size, material and function.

[SOURCE: ISO 24513:2019, 3.6.1.1]

3.4
failure
local inadmissible impairment of the operability of an *asset* (3.1) within an *asset system* (3.2) at a certain point in time on a certain asset

[SOURCE: ISO 24513:2019, 3.6.13]

3.5
failure data
data characterizing the occurrence of a *failure* (3.4) event

[SOURCE: ISO 24513:2019, 3.6.15]

3.6
failure rate
ratio of number of *failures* (3.4) of a given category to a given unit of measure

EXAMPLE Failures per unit of *assets* (3.1) and time, failures per number of actions.

Note 1 to entry: For treatment plants, pumping stations and similar facilities, expressed per year.

[SOURCE: ISO 24513:2019, 3.6.14, modified — Notes 1 to 3 removed.]

3.7
inspection
process to identify the actual status of an *asset* (3.1) or *asset system* (3.2) by observation and judgement accompanied as appropriate by visual control, handling, measurement, testing or gauging

[SOURCE: ISO 24513:2019, 3.5.8]

3.8
investigation
gathering of all information necessary for a decision-making process

Note 1 to entry: This should include both qualitative and quantitative information.

[SOURCE: ISO 24513:2019, 3.5.7]

3.9
level of service
parameter, or group of parameters, which reflect social, political, environmental and economic outcomes regarding the *service* (3.20) to users that the water utility delivers

Note 1 to entry: 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.

Note 2 to entry: A defined level of service can include any combination of the aforementioned parameters deemed important by the *asset* (3.1) owner, users or relevant stakeholders.

[SOURCE: ISO 24513:2019, 3.3.8]

3.10
life cycle cost
total cost of an *asset* (3.1) or its parts throughout its life cycle

Note 1 to entry: Total cost can include planning, design, construction, acquisition, *operation* (3.13), *maintenance* (3.11), *rehabilitation* (3.16) and disposal costs.

Note 2 to entry: Total cost excludes any residual value obtained during disposal.

[SOURCE: ISO 24513:2019, 3.6.2]

3.11
maintenance
combination of all technical, administrative and managerial actions during the life cycle of an *asset* (3.1) intended to retain it in, or restore it to, a state in which it can perform the required function

[SOURCE: ISO 24513:2019, 3.5.9]

3.12
management of assets
processes during the life cycle of an *asset* (3.1) to maintain value from an *asset system's* (3.2) existing *assets* (3.1) while ensuring an agreed *level of service* (3.9) and function of the system

Note 1 to entry: Processes include:

— all necessary activities for planning, design, procurement, construction/installation, *operation* (3.13), *maintenance* (3.11), *rehabilitation* (3.16) and disposal of *assets* (3.1) of drinking water systems, *wastewater systems* (3.25) and stormwater systems as a functional activity, including their review;

— setting objectives, and functional and performance requirements;

— establishing *strategic plans* (3.22), *tactical plans* (3.23) and *operational plans* (3.14);

— undertaking *investigations* (3.8) including establishing necessary databases, to assess the actual condition of assets during the lifecycle of the *asset system*.

Note 2 to entry: In ISO 24510, ISO 24511 and ISO 24512 the term "asset management" is used in the meaning of "management of assets".

[SOURCE: ISO 24513:2019, 3.5.2]

3.13
operation
action(s) taken in the course of normal functioning of drinking water systems, *wastewater systems* (3.25) or stormwater systems

EXAMPLE Monitoring and regulation or diversion of drinking water or *wastewater* (3.24).

[SOURCE: ISO 24513:2019, 3.5.10]

3.14
operational plan
documented collection of procedures and information that is developed, compiled and maintained in readiness for the conduct of *operations* (3.13)

[SOURCE: ISO 24513:2019, 3.1.16.1.1]

3.15
performance indicator
parameter, or a value derived from parameters, which provides information about performance

Note 1 to entry: Performance indicators are typically expressed as ratios between variables. These ratios can be commensurate (e.g. %) or non-commensurate (e.g. $/m^3).

Note 2 to entry: Performance indicators are means to measure the efficiency and effectiveness of a water utility in achieving its objectives.

[SOURCE: ISO 24513:2019, 3.9.6]

3.16
rehabilitation
measures for restoring or upgrading the performance of existing *asset systems* (3.2), including *renovation* (3.17), *repair* (3.19) and *replacement* (3.18)

[SOURCE: ISO 24513:2019, 3.5.11]

3.17
renovation
work incorporating all or part of the original fabric of an *asset* (3.1) by means of which its current performance is improved

[SOURCE: ISO 24513:2019, 3.6.16.2]

3.18
replacement
installation of a new *asset* (3.1), which incorporates the function of the old asset

[SOURCE: ISO 24513:2019, 3.6.16.3]

3.19
repair
rectification of a local breakdown or damage

Note 1 to entry: Repair can be planned [e.g. preventive *maintenance* (3.11)] or unplanned (e.g. in the case of damage).

[SOURCE: ISO 24513:2019, 3.6.16.1]

3.20
service
output of an organization with at least one activity performed between the organization and, in the first place, its user and, in the second place, a stakeholder

Note 1 to entry: The dominant elements of a service are generally intangible.

Note 2 to entry: Service involves activities and processes within an organization (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.

Note 3 to entry: Provision of a service can involve, for example, the following:

— an activity performed on a user-supplied tangible product [e.g. *wastewater* (3.24)];

— an activity performed on a user-supplied intangible product (e.g. processing new connection requests);

— delivery of an intangible product (e.g. the delivery of information in the context of knowledge transmission);

— the creation of ambience for the user (e.g. in reception offices).

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

Note 5 to entry: The word “service” in common English can also refer to the entity providing the actions related to the subject in question, as is implicit in such phrases as “bus service”, “police service”, “fire service” and “water or wastewater service”. In this context and usage, “service” implies the entity that is delivering the service, for example “the public transport of passengers”, “the provision of public security”, “fire protection and response”, and “delivering drinking water or collecting wastewater”. If “service” can be understood in this way, “water service” becomes synonymous with “water utility”; hence, in this document, in order to avoid confusion, only the definition in 3.20 applies.

[SOURCE: ISO 24513:2019, 3.3.7]

3.21
service life
period of time after installation during which an *asset* (3.1) or an *asset system* (3.2) meets or exceeds the technical and functional requirements

[SOURCE: ISO 24513:2019, 3.6.11]

3.22
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

[SOURCE: ISO 24513:2019, 3.1.16]

3.23
tactical plan
document identifying objectives to be pursued by an organization over the medium term, on the basis of priorities derived from influencing factors/indicators on performance, costs, risk and failure probability and scale of *failure* (3.4)

[SOURCE: ISO 24513:2019, 3.1.16.1]

3.24
wastewater
water arising from any combination of domestic, institutional, commercial or industrial activities, surface runoff and any accidental sewer inflow/infiltration water and which can include collected stormwater, discharged to the environment or sewer

Note 1 to entry: Wastewater can flow in separate or combined sewer systems.

[SOURCE: ISO 24513:2019, 3.2.2.2, modified — Note 2 to entry deleted.]

3.25
wastewater system
asset system (3.2) providing the functions of collection, transport, treatment and discharge of *wastewater* (3.24) and wastewater residues

[SOURCE: ISO 24513:2019, 3.5.12.3]

3.26
wastewater treatment plant
asset system (3.2) to transform wastewater by physical, biological and/or chemical means

Note 1 to entry: The wastewater treatment plant can contain, for example, pumping stations, retention and detention tanks, stormwater storage and overflow facilities, screens, sedimentation tanks, aeration tanks, filters, lagoons, sludge treatment facilities, chemical facilities, odour control and outflow facilities including grilles.

Note 2 to entry: Pumping stations and retention and detention tanks can also be sited in the wastewater network.

[SOURCE: ISO 24513:2019, 3.5.15]

4 Principal aspects of the management of assets

4.1 Objectives and requirements

4.1.1 Objectives

The key generic objectives for the management of assets of wastewater systems are identified from ISO 24510 and ISO 24511:

— protection of public health and safety;

— meeting users' reasonable needs and expectations;

— occupational health and safety;

— promoting the sustainability of the wastewater utility;

— providing services under usual and emergency situations;

— providing sustainable development of the community;

— protection of the environment.

Wastewater utilities should aim to manage their facilities systematically and efficiently in order to sustain their functions. This should take place on the basis of clearly defined objectives, based on assessment and forecasting of the condition of their often extensive and complex facilities.

Setting objectives for the management of assets should help to ensure that wastewater utilities conform with an agreed and sustainable level of service, while also exerting a major influence on the economic performance of the wastewater utility and taking into account risks to the achievement of those objectives. The level of service should be well defined, communicated, tied to risk and current, as customized to a particular wastewater utility.

For further information on objectives of management of assets for a wastewater system see Annex A.

4.1.2 Functional requirements

Functional requirements should be established to aid the achievement of the objectives.

Functional requirements of a wastewater utility cover treating and pumping wastewater and sludge by means of treatment plants, as well as pumping wastewater and sludge in wastewater networks (as part of the wastewater system), including the effects of discharges on receiving water bodies. A variety of equipment and facilities support the main functionalities and are also subject to management of their associated assets to ensure sustainable discharge in the natural environment. The functional requirements should be considered in respect of the whole wastewater system to ensure that additions or modifications to the system do not result in failure to meet the target(s).

Functional requirements should be established which, while taking into account sustainable development and whole life costs, including indirect costs (e.g. traffic congestion, military aid provided to the civil authorities), ensure that wastewater systems treat and dependably discharge their contents without causing unacceptable environmental nuisance, risk to public health, or risk to personnel working therein.

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

Table 1 — Relationship between objectives and functional requirements

Examples of functional requirement	Objective						
	Protection of public health and safety	Protection of occupational health and safety	Protection of the environment	Meeting users' reasonable needs and expectations	Promoting sustainability of the wastewater utility	Providing service under usual and emergency situations	Promoting sustainable development of the community
Elimination of undesirable constituents in the influent	XXX	XXX	XXX	XXX	XX	XX	XX
Protection from flooding	XXX	XX	XXX	XXX	X	XXX	XXX
Maintainability	XX	XXX	XX	XX	XX	XX	XX
Protection of receiving water bodies	XXX	XXX	XXX	XXX	XX	XX	XX
Protection of groundwater/ watertightness	XXX	—	XXX	XXX	XX	X	XXX
Biological hazards	XX	XXX	XXX	XX	XXX	X	X
Prevention of odours and toxic, explosive and corrosive gases	XXX	XXX	XXX	XXX	XX	XXX	XXX
Prevention of noise and vibration	XX	XXX	X	XXX	X	XX	X
Sustainable use of products and materials	—	X	XX	XX	XXX	X	XXX
Sustainable use of energy	—	—	XX	XX	XXX	X	XXX
Structural integrity and design life	XXX	XXX	XXX	XXX	XXX	XXX	XXX
Maintaining the flow	XX	XX	XXX	XXX	XX	XXX	X
Effluent quality	XXX	XXX	XXX	XXX	XX	XXX	XX
Wastewater by-products	XXX	XXX	XXX	XX	XXX	XX	XX
NOTE The number of Xs gives guidance on the importance of the requirement in achieving the objectives.							

4.1.3 Performance requirements

In order to evaluate the performance of the wastewater system and to allow development of design criteria, measurable performance requirements should be determined from each functional requirement.

The process for determining performance requirements is illustrated in Figure 1.

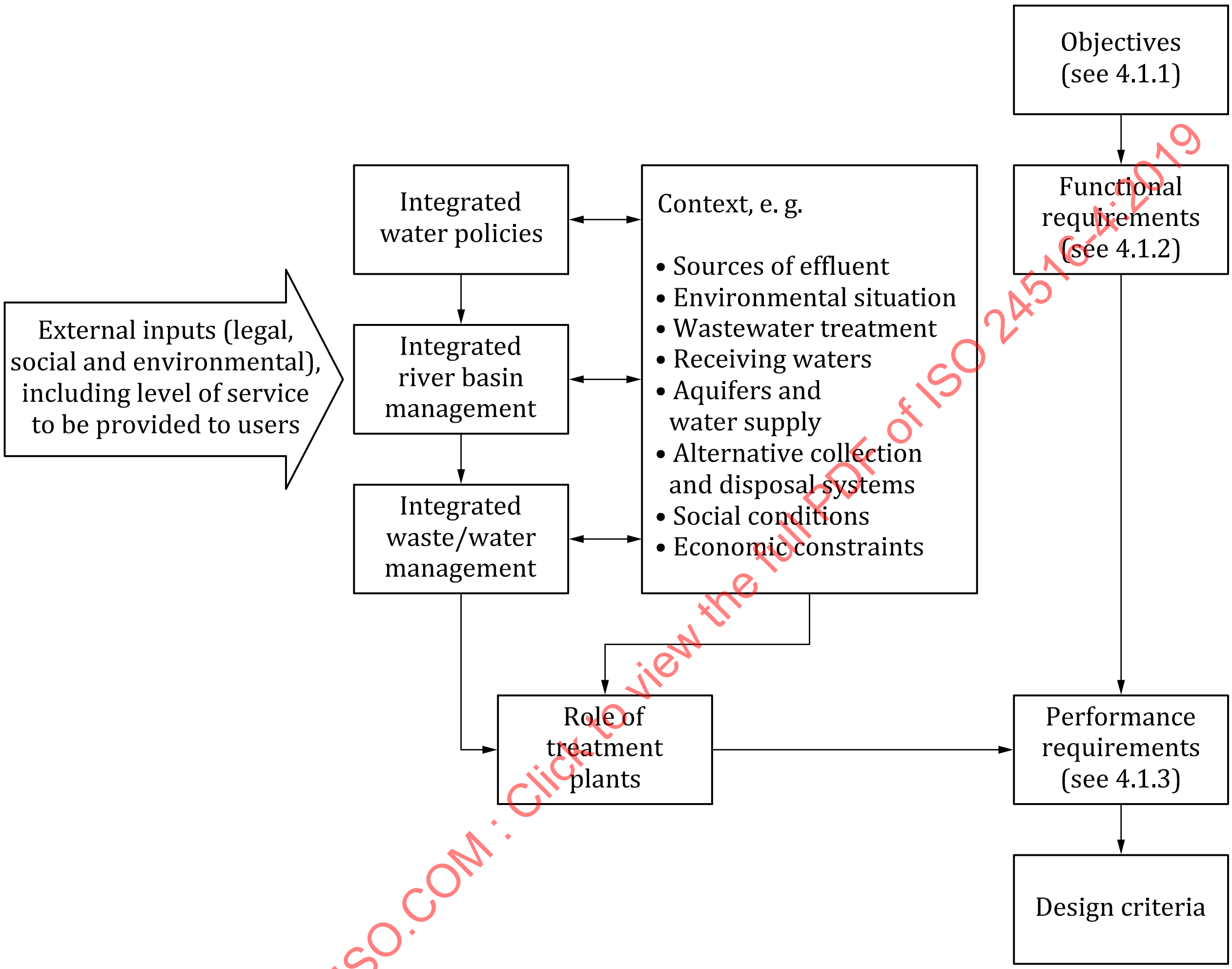


Figure 1 — Process for determining performance requirements

For each functional requirement, there can be legal requirements, public expectations and financial constraints influencing the performance requirements. Public expectations should be reflected in the level of service set by the utility to provide to its users.

For each aspect of performance, different levels can be required, for example:

a) trigger levels which justify early upgrading action according to priority;

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.

Performance requirements should be reviewed periodically and updated, if necessary. The performance requirements for the wastewater system should be updated after major extension, maintenance or rehabilitation.

In principle the performance requirements for a rehabilitated wastewater treatment plant should be the same as those for a new treatment plant.

Performance indicators are essential tools for the understanding of the actual and desired performance of the infrastructure of a wastewater utility, and in parallel, enable indicator-supported infrastructure planning and decision making. Reasonably designed and applied, performance indicators provide information about the condition of the assets and the level of their contribution to the achievement of the objectives of a wastewater utility.

Performance indicators should be defined at strategic, tactical and operational levels, for example:

— strategic: conformance with effluent discharge requirements;

— tactical: reduction of biochemical oxygen demand (BOD), nutrient reduction;

— operational: use of chemicals and energy per m^3.

The performance indicators provide information on how actions at the operational level contribute to achieve strategic-level objectives. Strategic-level indicators are often called “outcomes”, while operational- and tactical-level indicators are called “inputs” and “outputs”, respectively. Operational performance indicators should be compared with action plans [see 7.4 b)].

For further information on objectives and functional requirements see Annex A.

4.2 General aspects

4.2.1 General

In management of assets a distinction can be made between two principal focal points:

— the wastewater utility or responsible body in question;

— that organization’s wastewater system to be managed.

The former could include, for example: strategic financial, reputational and non-operational assets as part of ensuring the wastewater utility's overall objectives are met.

The latter should take into account:

— attention to stakeholders’ (e.g. users, operator, relevant authorities, responsible bodies) requirements, needs and expectations;

— sustainability of the wastewater system and the provided service;

— management of risk, including occupational health and safety exposure;

— local conditions (e.g. climatic, social, technical);

— financial stability of the utility.

4.2.2 Principal aspects — Wastewater utilities

The management of the physical infrastructure of wastewater utilities is recognized as a critical activity to realize users’ and other stakeholders’ expectations. Key activities include:

— the determination of the utility’s current and longer-term objectives;

— planning and implementing activities to achieve objectives;

— the means of measuring the performance of the utility in meeting these objectives;

— the prediction of future amounts of wastewater as an additional basis for rehabilitation.

The management of the wastewater utility’s assets should be directed towards ensuring the utility’s objectives are met.

Additionally, for ensuring long economic life cycles, proper operation and stable wastewater service this should include:

— knowledge of the layout of the entire wastewater system;

— knowledge of the entire wastewater system together with knowledge on costs (planning, constructing, operation, maintenance and decommissioning);

— knowledge on availability and need of resources;

— selection of appropriate materials and components;

— choice of installation technologies and installation contractors;

— quality control of technologies, facilities, materials used and of wastewater and effluents;

— maintenance of the wastewater system and its assets including routine and incident related inspection and investigation;

— monitoring of operational conditions;

— monitoring the wastewater system's environmental conditions.

Efficient management of assets ensures a continuous provision of the level of service as defined by the wastewater utility in order to meet users' and wider stakeholders' expectations and minimize life-cycle costs.

Management of the assets includes:

— education and training of the personnel to achieve relevant competences;

— maintaining an up-to-date wastewater system inventory;

— monitoring and documenting data;

— assessing the condition of the wastewater system;

— planning, maintaining or rehabilitating the wastewater system;

— operation of the wastewater system in such a manner so as to increase service life while maintaining the agreed level of service;

— optimizing life cycle costs;

— identifying and managing risks;

— ensuring stable wastewater service by taking into account the timing and duration of various rehabilitation works;

— ensuring the wastewater system is utilized/operated as intended;

— protecting the environment from detrimental impacts resulting from the wastewater assets' use.

4.2.3 Principal aspects — Wastewater systems

The management of assets of wastewater systems should cover the complete wastewater infrastructure and the interrelationship of all assets of the wastewater system such as wastewater networks, pumping stations, retention and detention tanks and treatment plants including the resulting effluent quality and its disposal/reuse as well as solids' disposal facilities. In addition, the management of assets should consider changes in needs and expectations/requirements of users and other stakeholders, change in behaviour or usage as well as environmental effects such as climate conditions, population migrations, and demography as far as data are or can be made available. This can be laid down in a wastewater master plan, which can be a stand-alone document, or captured within the strategic plan. See also an example for the content of a wastewater master plan in Annex B.

Hence this document should be used in conjunction with other standards regarding management of assets on wastewater systems such as ISO 24516-3.

Wastewater systems are used to provide a service to their users and communities. This can be briefly (and typically) described as:

— removal of wastewater from premises for public health and hygienic reasons;

— prevention of flooding in urbanized areas;

— protection of the environment both natural and built.

In general, a wastewater system has the following potential functions:

— collection;

— transport;

— pumping;

— retention and detention;

— treatment;

— discharge;

— reuse.

This includes monitoring of water and sludge quality at relevant stages in the treatment plant.

4.2.4 Integrating the principal aspects

Management of assets is the application of the wastewater utility's management of asset principles, as described in this document, within the management of the wastewater system comprising treatment plants and wastewater networks and implemented within the framework of integrated wastewater system management, see 4.4.1.

4.3 Risks and life cycle aspects

4.3.1 Risk

Risk considerations are necessary at all levels in the management of assets — the strategic, the tactical and the operational levels.

Appropriate treatment of risks arising within the context of an organization is an important objective in the management of that organization's assets. Risk treatment is typically done by the introduction or modification of existing risk controls. Selection of the most appropriate risk controls should result from a process of assessing organizational hazards (e.g. arising from an asset's positioning or failure). Appropriate countermeasures can then be introduced in a prioritized manner. Such measures can include operation and maintenance, extension and disposal activities as well as rehabilitation.

There are many alternative techniques for identifying, analysing, evaluating and treating risk in different fields (see IEC 31010, and the water sector specific EN 15975-2). The risk assessment methodology proposed in this document is based on generally recognized risk assessment principles (e.g. ISO 31000).

These principles involve:

— risk identification (in this case principally by hazard analysis);

— risk analysis;

— risk evaluation;

— risk control.

Risk control can include risk treatment and risk mitigation.

Hazard analysis involves study of a risk event's occurrence and the likelihood that an event can occur. The utility should define its utility-specific risk analysis approach and criteria for risk evaluation, based on organizational 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 × likelihood ratings against the organization's risk criteria) - using a risk matrix to present the results. Systematically estimating the cost of individual risks' impact can aid overall risk prioritization.

The evaluation 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 benefits techniques, see 7.3.

Wastewater-related asset risks can be categorized into the following two groups:

a) **non influenceable risks**, such as natural disasters (e.g. earthquakes, storms, floods) or economic situations.

b) **influenceable risks**, such as events arising from accidental damage, facility deterioration, service restriction or interruption by blockages, damage, malfunction or deterioration of effluent quality.

The following are a few examples of asset data relevant for assessing impact (of failures):

A treatment plant's:

— sizing;

— function;

— proximity to other significant assets, infrastructures or areas;

— access constraints;

— rehabilitation cost.

The following are examples of asset data reports relevant for assessing likelihood (of failures):

— abnormalities in wastewater quality;

— exceedance of parametric values;

— maintenance;

— telemetry;

— employee feedback;

— incident;

— condition;

— stakeholders' complaints;

— security;

— social behaviour;

— environmental impact;

— rehabilitation costs.

4.3.2 Life cycle

Life cycle cost should be minimized by keeping the wastewater system in stable operating conditions as stated in the objectives. This should include:

— optimized maintenance planning;

— inspection;

— use of suitable construction methods and durable materials;

— co-operation with other organizations;

— energy management;

— optimized stand-by service;

— proper control of operational processes;

— proper control of the wastewater system's use (e.g. waste discharge control);

— efficient deployment of staff and accomplishment of tasks (by qualified and/or certified contractors, if necessary), but retaining core competences (e.g. organizational, operational and technical) in the wastewater utility;

— participation in benchmarking projects;

— demand-based "materials management" and control (procurement and stock keeping).

For example, to rehabilitate facilities, the priority of a project should be determined in the framework of the budget while aiming to minimize the life cycle cost of each asset. To avoid simultaneous rehabilitation and equalize rehabilitation cost, service life of some assets should be prolonged or shortened by advancing or delaying rehabilitation measures.

4.4 Structuring the process for management of assets

4.4.1 General

Integrated management of assets in wastewater treatment plant is the process of achieving an understanding of the existing and proposed wastewater system, and using this information to develop strategies to ensure that the hydraulic, environmental, structural, process engineering and operational performance meets the specified performance requirements taking into account future conditions and efficiency.

The integrated wastewater treatment plant management process is illustrated in Figure 2.

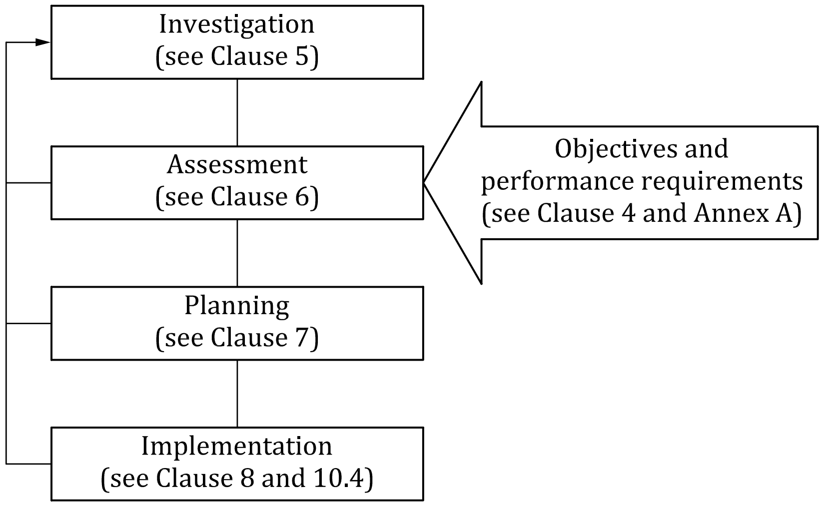


Figure 2 — Integrated wastewater treatment plant management process

The integrated wastewater treatment plant management process has four principal activities.

1) an appropriate level of investigation of all aspects of the performance of the wastewater system;

2) assessment of the performance by comparison with the performance requirements including identification of the reasons for the performance failures;

3) developing the plan of measures to be taken;

4) implementation of the plan.

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

Integrated wastewater treatment plant management forms the basis for the operation, maintenance and rehabilitation of the wastewater system. The information should be regularly updated for the future management of the wastewater systems.

For large wastewater systems, for example one serving a large city, a strategic outline integrated wastewater treatment plant management plan can first be developed following an outline investigation of the whole asset system. More detailed plans can then be developed for each sub-catchment or treatment plant within the context of the strategic outline plan.

The integrated wastewater treatment plant management plan should be further developed during the implementation phase by subsequent investigation, assessment and planning to develop work programmes and individual projects to implement the plan.

The given boundary conditions should be considered.

4.4.2 Strategies for the management of assets

The strategies for the management of assets should be based on objectives and requirements (see 4.1) included in the wastewater master plan. The risks of not achieving these objectives and requirements should be identified and managed appropriately. Based on whichever of the following two strategies, the **condition-based** or **inspection strategy** or the **incident-based** or **failure strategy** is chosen, the risks can be estimated and controlled.

To increase the likelihood of achieving the objectives and requirements as stated in 4.1 the wastewater infrastructure assets should be managed and maintained according to the **condition-based** or **inspection strategy**.

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

The **condition-based** or **inspection strategy** takes into account 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 cannot 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. Based on this strategy the risks can be estimated and controlled in relation to the objectives determined in accordance with 4.1.

Organizational constraints, continuance of existing practices or acceptance of low impact risks' consequences 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 run. Probable consequences can include:

— deterioration of assets leading to decrease of value;

— inadequate operating safety margins;

— increased failure rates;

— flooding.

The risk of failures and inadequacies can be extremely high. An **incident-based** or **failure strategy** usually can only be successful if the risk linked to the asset is low and should not be affected by an increased downtime.

Fundamental prerequisites for economically efficient management of assets should be defined as early as possible, including the design and construction phases of wastewater infrastructure.

Strategic planning of wastewater treatment plants should intersect with the strategic planning for the development of the whole wastewater system. Although there are technically very different requirements, they are inherently closely coupled.

Wastewater systems are typically physical infrastructures with a very long useful life. Periods of many decades should, as far as possible, be considered in the strategic planning.

An appropriate level of care should be exercised during planning on the strategic level due to the very high levels of investments in the wastewater system and the technical and financial implications of subsequent adjustments.

4.4.3 Periods of planning

The sustainable process for the management of assets is, on the basis of the planning period under review, subdivided into the following three interdependent logical steps, see Figure 3:

— long-term planning (strategic planning);

— medium-term planning (tactical planning);

— short-term measures (operational planning).

NOTE The duration of the planning stages is dependent on local circumstances and the context of the installation environment.

Common time horizons are:

— strategic planning, about 20 years to 40 years;

— tactical planning, about 2 years to 5 years;

— operational planning, next year.

The step “strategic planning” focuses on the scope of measures and the budgets required to achieve and to maintain treatment plants' condition levels.

In the step “tactical planning”, the required measures should be determined and prioritized for a medium-term period based on a wastewater system evaluation and, at that time, the technologies and materials should be preselected.

In the step “operational planning”, the actual execution is then examined and fixed taking possible alternative measures into consideration (e.g. execution of the rehabilitation measures in terms of the degree of efficiency of pumping stations, combined heat and power (cogeneration) plants, centrifuges, material and construction methods).

The logical steps cannot be considered as independent and their results with regard to management strategy, planning and implementation measures should be harmonized not only with one another, but also within the strategic approach and capacity planning (e.g. upgrading, modification, consolidation, decommissioning of parts of the assets or the asset system).

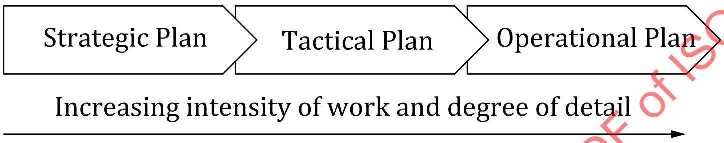


Figure 3 — Logical steps for the implementation and evaluation of targets for the management of assets

4.4.4 Strategic level activities

Decision-making support requires in the first step the identification of measurable strategic objectives (see 4.1) and the necessary evaluation and measurement of the objectives. Common activities related to determining strategic objectives should include the following:

— establishing acceptable/required levels of service, public and occupational safety, public and occupational health protection, environmental protection and user satisfaction;

— expressing those levels in the form of performance indicators;

— linking those performance indicators to asset performance indicators;

— establishing adequate tariffs and billing coverage and recovery rates suitable in time to ensure sustainable revenues;

— quantifying sustainable infrastructure funding requirements and ensuring predictability;

— assessing capacity against future demands;

— evaluating and adopting maintenance and rehabilitation strategies from the possible approaches to draft the strategic plan;

— establishing effective risk control measures and necessary levels of resilience within the entire wastewater system;

— controlling costs.

4.4.5 Tactical level activities

Activities on a tactical level should include:

— analysing infrastructure asset life cycles;

— establishing information to be collected at the operational level;

— establishing a system for managing information;

— analysing reported information;

— prioritizing infrastructure spending from available funds;

— maintaining an accurate asset data collection system;

— assessing the risks of asset failure or inability to meet the intended function;

— ensuring that the required maintenance is performed;

— controlling costs;

— preselection of process and rehabilitation technology and materials.

A major activity at the tactical level is the process of reviewing indicators to determine only productive, useful and coherent information, to avoid overloading the information management process. The information should be manageable and relevant.

4.4.6 Operational-level activities

Activities on an operational level should include:

— collecting, monitoring and reporting asset operational information and condition, see Clause 5;

— controlling costs;

— planning maintenance schedules;

— implementing preventive and corrective maintenance activities;

— operating the wastewater system within its operational parameters;

— responding to incidents, asset failures and emergencies, and restoring service;

— selection of process and rehabilitation technology and materials;

— implementation of rehabilitation projects.

5 Investigation

5.1 General

The investigation should be carried out in order to make an assessment of the condition and the performance of the wastewater treatment plant and its components.

Investigation is the first stage in the integrated management of a wastewater treatment plant as described in 4.4.1.

Damaged, defective or incorrectly sized assets represent a hazard for wastewater service provision and the protection of receiving water bodies, groundwater and soil.

Data about age, period of operation, maintenance intervals and history of disorder support investigation and condition assessment. The results of the investigation should be backed up conveniently in a database to facilitate subsequent evaluations. The structure of the database should build on an asset labelling system, which assigns a unique identification to each important asset.

In addition to the assessment of the condition of assets an investigation of the relevant processes should be done. This could, for example, be done on the basis of individual performance tests of functional groups, or on the whole treatment plant. These results should be documented accordingly.

The problems found in existing wastewater treatment plants are frequently interrelated and upgrading works can often be designed to overcome a number of problems at the same time. The investigation and planning should be carried out on complete drainage areas so that all problems and their causes can be considered together. In large wastewater systems, it can be necessary to start by investigating appropriate parts of the treatment plant. The procedures described in this document can be applied in any wastewater system, but detailed application should take account of the age, capacity, location and type of the treatment plant, the materials used in its construction, together with functional and climatic factors.

5.2 Purpose of investigation

Investigation should be carried out in order to make an assessment of the performance and the condition of the wastewater system. This can include:

— investigation aimed at tactical planning;

— investigation aimed at operational planning.

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

The assets of the wastewater treatment plant included in the investigation should be those that are necessary to fulfil the purpose of the investigation. Examples include retention and detention tanks; pumping stations; inlet works; screens; sieves; grit chambers; light liquid/fat/oil/grease separators; treatment plant tanks (stormwater, balancing, flocculation, filtration, flotation or settlement and aeration); reactors; filters; lagoons; ponds; wetlands; digesters; dewatering equipment; outfalls; and monitoring and control facilities. Data on assets of related wastewater networks should also be taken into account in regard to their interaction with treatment plants.

5.3 Determine the scope of the investigation

Following the review of the current performance information, it is possible to decide whether to carry out an investigation and whether the extent of the problems justifies an investigation of all facilities of the wastewater system. The extent and detail of the subsequent investigation of the hydraulic, environmental, structural, process technology and operational aspects should be determined.

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 Types of investigation

5.4.1 Hydraulic investigation

Testing and inspection procedures can be required in order to ensure an adequate evaluation of flows (wet and dry weather). Surveys can include precipitation and flow measurements. The results of the hydraulic investigation can influence sewer control management and the operational management of the treatment plant and pumping station(s). These dependencies between pumping station, wastewater treatment plants, retention and detention tanks and the wastewater network should be taken into consideration.

In some cases, a hydraulic or treatment plant simulation model is needed to understand the hydraulics. The interaction between pumping stations, treatment plants, retention and detention tanks and the network should be considered. Such a flow simulation model or a treatment plant process engineering simulation model should ideally be based on an as-built report updated after onsite investigation of the main works.

5.4.2 Investigation of the process technique

The electrical and mechanical equipment in wastewater treatment plants can be controlled by a process control system. Typically, this process control system consists of hardware and software. The entire process control system should be monitored regarding interfaces with other IT-systems or external communication links, and non-conformities investigated. The aim is to 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 IT security requirements. The results of these studies and activities should be documented as well as every subsequent change in the process control system.

5.4.3 Environmental investigation

The environmental impact depends on the nature of the wastewater and its potential to escape from the asset system.

The quality of receiving water bodies should be ascertained to see whether they meet requirements and if not, whether the wastewater system is a significant factor.

Consideration should be given to other environmental factors such as noise, odour, visual intrusion and potential soil contamination.

The investigation can include[13]:

— review of quality of discharged wastewater;

— wastewater quality measurement;

— wastewater quality simulation modelling;

— water quality/pollutant condition surveys of discharged water from wastewater treatment plant;

— impact surveys on receiving water bodies;

— leak-tightness testing;

— groundwater quality investigations;

— impact surveys, for example odour and noise.

5.4.4 Structural investigation

The structural investigations can include either a complete survey of the wastewater treatment plant or a more selective approach. Where appropriate, investigations should include the following: retention and detention tanks; pumping stations; inlet works; screens; sieves; grit chambers; light liquid/fat/oil/grease separators; treatment plant tanks (storm, balancing, flocculation, filtration, flotation or settlement, and aeration); reactors; filters; lagoons; ponds; wetlands; digesters; dewatering equipment; outfalls; monitoring and control facilities; and other buildings. Consideration should be given to the age, condition, location and resilience (e.g. to natural disasters) of existing assets, including exposure to geotechnical influences.

Where appropriate, other qualitative and quantitative investigation techniques should be used. These include laboratory analyses and field condition assessment to identify the integrity and remaining strength of an asset.

5.4.5 Operational investigation

Existing operational procedures, inspection schedules and maintenance plans should be identified and documented.

The frequency and location of recorded operational incidents (e.g. flooding, process interruptions) should be reviewed.

The impact of operational problems on the hydraulic, environmental and structural performance of the wastewater treatment plant should be determined from incident records.

Incidents such as unusual noise, vibration, heat and odour should be documented.

The causes of significant recurrent operational incidents should be investigated.

To deal with operational problems in an efficient way, it is necessary to investigate and understand the causes.

Control system technologies enable operators to evaluate more complex causes of failures through trend analysis providing an opportunity to assess interactions among the asset types. It applies in particular with regard to the interactions between wastewater networks and wastewater treatment plants and between asset types within, and across, these systems.

To deal with operational problems in the most efficient way, it is necessary to investigate and understand their causes and effects. Investigations can be required to determine the:

— location of assets;

— condition of assets;

— cause and location of failures;

— consumption of energy;

— quality of construction or repair of structural and technical equipment.

Operational investigation techniques available include:

— diverse electronic sensors;

— flow metering;

— sampling and analysis;

— leak monitoring.

Irrespective of the strategy and the methods used, wastewater infrastructure assets should be monitored on a permanent basis and their components and operating equipment should be maintained and inspected regularly for their operating condition and functionality in accordance with functional asset requirements.

Even after commissioning of the wastewater infrastructure assets a routine monitoring of the level of service, and particularly an inspection of the age-related conditions of the assets and their maintenance, should be started. The designer and/or the owner or operator should specify the nature and frequency of the maintenance and inspection of the asset system or single assets. If condition data based on routine inspection are not available, all other available data based on condition assessment should be used.

A sufficient and reliable database of the inventory and condition of wastewater infrastructure systems is essential for maintenance, including strategy, tactics and execution. It is based on the qualified and quality-assured collection, processing, evaluation and storage of asset-related data. All maintenance data, in particular from inspections, should therefore be recorded and documented.

Measurable inventory data enable decision makers to better identify the consequences of their decisions and to avoid many errors in financial decisions that result from incomplete knowledge of their infrastructure facilities and their requirements or demands. Without such understanding operational problems can subsequently arise in the various components of the wastewater treatment plants.

5.5 Data collection

5.5.1 General

Acquisition of data can be important but carries a cost. The wastewater utility should consider what data are important to acquire promptly and what further data should be acquired opportunistically. Details of types of data associated with a range of objects that can be important to inform the wastewater utility's decision-making process are described in 5.5.2 to 5.5.5. The wastewater 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 at first the inventory should be updated where required and any other information should then be collected during operational investigation of relevant components, such as hydraulic volumes, inflow constituents, and environmental and structural factors.

5.5.2 Data requirements

The quality of data should be assessed, taking into account whether it is:

— complete;

— compatible;

— accurate;

— at a suitable scale;

— consistent;

— current;

— credible.

5.5.3 Inventory data

Inventory data provide essential technical information on the assets of the facilities within a wastewater treatment plant. Table C.1 gives examples of inventory data.

5.5.4 Condition data

5.5.4.1 Failure data

Failure data provide technical information on failures found in aggregates of assets of wastewater treatment plants and should be linked to inventory data. The following data should be collected:

— date of documentation, after final remedy;

— date of failure occurrence;

— location (e.g. asset identification number, location);

— point of failure;

— type of failure;

— cause of failure (e.g. natural deterioration, damage due to others' construction work);

— type of remedy (repair, renovation, replacement);

— cost of eliminating failure;

— cost of putting back into operation and cost of temporary remedy;

— consequence(s) of failure (e.g. exceeding the parametric values, flooding, interruption of a treatment process).

The data on failures which were caused by events over which there is no control, for example natural disasters such as earthquakes or floods, can provide crucial information and are particularly important for the rehabilitation strategy as well as for contingency and emergency planning. See also Table C.2.

5.5.4.2 Further condition data

In addition to failure data, more information on the condition of facilities and components of wastewater treatment plants should be acquired as it provides valuable information on the prioritization of rehabilitation measures.

The availability of condition data on wastewater treatment plants can be limited, with the data methods differing fundamentally from the collection of inventory and failure data.

The following data should be collected, if they appropriately describe the condition of the assets and are obtainable:

— date of condition data collection;

— definition of the assets' respective technical facilities (e.g. coordinates, address);

— identification and plausibility information (e.g. material, size, definition of facility, part of the asset);

— condition/failure (e.g. temperature of bearings, efficiency of pumps or motors);

— soundness and resilience to natural disasters;

— operational incidents;

— context data.

Context data, for example trade effluent in the catchment area, electricity supply, condition of the surface water body, earth movements/mining activities or topography, provide technical information about the local surroundings of wastewater systems, which should be factored into the risk assessment process. See also Table C.2.

5.5.5 Operational data

In addition to the data mentioned in 5.5.1 to 5.5.4, operational data should be acquired as it provides valuable information on the facilities and components and on the prioritization of rehabilitation measures. See Table C.3.

5.6 Data registering and data assignment

5.6.1 Data registering

The data to be registered as defined in 5.5 should be compiled, integrated, processed and safely stored and readily recoverable by the utility. The stored data should be checked and updated periodically or appropriately. They form the basis for developing maintenance plans and strategies.

The data collection process itself determines the value of the data for asset maintenance. The data should relate to the asset inventory (see examples in Annex C and 5.4 and 5.5). The value of the data increases in line with their quantity and quality registered and with the possibility to assign individual data to the respective wastewater system under consideration.

Table C.1 applies to the inventory data which should be registered, Table C.2 applies to failure and other condition data, and Table C.3 applies to operational data which should also be registered. Data collection should be comprehensive, uniform, continuous, free from interpretation and based on previously and unambiguously defined default values ("multiple choice"). Free text should be avoided because it offers only limited evaluation possibilities.

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 wastewater system.

5.6.2 Data assignment

All inventory, condition and context data registered should be correctly assigned to the associated asset types (e.g. mechanical equipment, electro-technical equipment, concrete tanks/buildings) and/or individual assets. Likewise, failure data (e.g. ageing, fatigue, damage caused by other processes or facilities, poor maintenance) should be registered in such a way as to enable the retroactive elimination of events not relevant to maintenance.

Inventory, condition and context data can be used for devising rehabilitation strategies and tactics, depending on the asset to which they are assigned.

5.6.3 Locational referencing

Using the above-mentioned databases for medium- and short-term rehabilitation planning can require locational referencing and should be given in absolute elevation referenced to a datum level, for example sea level at a specific location and the unambiguous assignment of data records to their associated assets. Using selective locational referencing, condition, context and operational data can provide important information when defining a rehabilitation strategy.

Capturing data [e.g. in a geographic information system (GIS), process and instrumentation (P and I), flow sheet, computerized maintenance management system (CMMS), enterprise-resource-planning (ERP) system, asset information system] is recommended for processing and using maintenance-related data. Reference to individual assets should be preserved even when decommissioned assets have ceased to form part of a current facility. Historical data also supply important information for devising a rehabilitation strategy.

5.7 Review existing information

The collection and review of all available relevant information about the wastewater treatment plant (asset inventory) should be carried out and is the basis from which all other activities are subsequently planned.

A review should also be undertaken of the information required to manage the wastewater system.

This information should be assessed to determine what further information is required in order to carry out the investigation.

5.8 Inventory update

Where the inventory is incomplete it should be updated so that a sufficient record of the wastewater system is available to carry out the investigation.

NOTE The update of the other information is included in the hydraulic, environmental, structural and operational 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 (e.g. design documents, information system). Mapping the data workflows among their sources and recipients can enable better functionality, efficiency and quality.

5.9 Review of performance information

An indication of the type of performance problems, if any, in existing systems is likely to be known through reports of incidents such as breakdowns; malfunction of machines or valves; or deterioration of wastewater quality (exceeding of limit or guidance values) within the treatment process. Data on such problems can be gathered from online monitoring and from previous investigations. 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 other such information include:

— hydraulic performance analysis;

— performance of mechanical/electrical equipment (e.g. metering or control devices);

— results of monitoring, performance and condition.

Where large numbers of treatment plants or treatment steps are in need of investigation, the existing information collected can also be used to assign priorities to the investigation of the perceived problems in each drainage area (for example by comparing the cost of the investigation with the benefit that might be achieved). These priorities can be used to draw up a comprehensive program with the intention to investigate facilities with the most serious projected problems or risks first.

5.10 Planning of investigation

The following should be evaluated for modelling of survey work:

— target facilities and period for investigation;

— determination and type and extent of survey (see 5.4);

— suitable survey method, items, standards;

— estimated cost.

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

5.11 Performance testing

The performance of assets in wastewater treatment plants should be assessed during construction, at the completion of the construction stage and also during the operational life of the wastewater system. The following are examples of applicable test methods:

— efficiencies of pumps, function and tightness of valves;

— hydraulic performance;

— visual inspection;

— monitoring of equipment or process availability over the time period in question;

— wastewater quality measurement under different load conditions until going to the peak load, possibly beyond the design limit;

— dry weather flow assessment;

— monitoring of inputs to the treatment plant including substances toxic to the treatment process;

— monitoring wastewater quality at various treatment steps;

— monitoring effluent quality, quantity and frequency at point of discharge to receiving water bodies;

— monitoring of discharge from wastewater network to treatment works.

The scope and the test methodologies to be undertaken to determine the performance of wastewater treatment plants depend on whether it is a new asset, a rehabilitated asset, or a long-established asset being tested.

The effectiveness of maintenance or the methodologies to be followed should be assessed by comparing the performance of the wastewater treatment plant with the wastewater utility's objectives. In the case of a condition-based strategy the equipment availability can be used as an assessment.

In addition, for reactive maintenance, target response times can be used as an assessment. This also forms the basis for future planning.

6 Assessment

6.1 Principle

Once the wastewater system has been investigated, the next stage is to examine the results to identify those areas requiring action.

The performance of the wastewater system should be assessed against the performance requirements (see 4.1.3). The performance assessment should include the evaluation of risks of failure to achieve the performance requirements (see also Reference [6]).

Figure 4 shows the process of assessment.

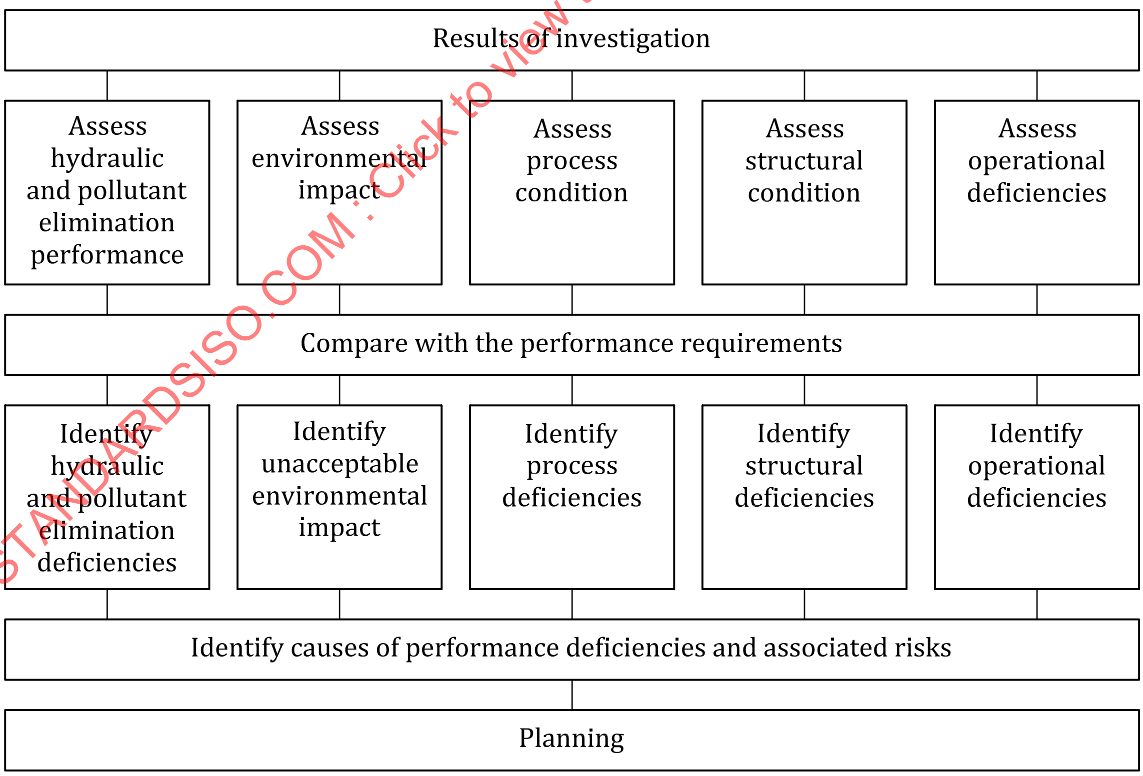


Figure 4 — Process for assessment

6.2 Assessment of hydraulic and pollutant elimination performance

Based on the results of the investigation of the processes, the performance of the wastewater treatment plant should be assessed with regard to the requirements for the maximum required power demand. This should consider peak flow, peak of polluting load and dry weather conditions depending upon the sizing of the facilities. The resilience for normal operation should be safeguarded by the necessary security and redundancy arrangements in accordance with risk management principles.

The results of the hydraulic and pollutant elimination investigations and/or the verified flow simulation model and the treatment plant process engineering simulation model should be used to assess the hydraulic and pollutant elimination performance of the wastewater system for a range of rainfall conditions and polluting loads related to the performance requirements.

6.3 Assessment of process performance

The treatment process performance of a treatment plant should be monitored by manual and online measurement of the wastewater quality at the prescribed interval and using the prescribed method of analysis. The measurement should be done at different treatment stages in the wastewater treatment plant in order to more easily identify differences to the target values.

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 environmental impact

The results of the investigations should be considered together with information on the frequency, duration and volume of discharges to receiving water bodies, determined using a verified flow simulation model or a treatment plant process engineering simulation model where this is available, or from site measurements. This information should then be used to assess the environmental impact (including impact on soil and groundwater) of the wastewater system.

The results of the structural investigation, the trade effluent survey and other relevant investigations should be examined to identify:

— sources of hazardous effluents;

— exceedance of permissible concentrations and discharges including social consequences;

— other deviations from permits.

6.5 Assessment of structural condition

Further criteria are relevant for the assessment of the structural condition of wastewater treatment plants such as operational availability, stability, protection of the equipment against environmental influences, flood protection and flood control, lightning protection, fire protection and escape routes, and protection against unauthorized access.

6.6 Assessment of operational performance

The operational performance of the wastewater system can be assessed by a number of measures. For example, the number of operational incidents or failures occurring within a given time period. This should be recorded in a database.

6.7 Comparison with performance requirements

The results of the assessment of the hydraulic, environmental, structural and operational performance should be brought together so that the overall performance of the wastewater system and its assets can be compared with the performance requirements (see 4.1.3).

Performance indicators are a method of comparing the overall performance of wastewater systems with performance requirements and for comparing different treatment plants. They can also be used as a basis for benchmarking purposes (see ISO 24523). Any performance indicators used should be:

— clearly defined, concise and unambiguous;

— verifiable;

— simple and easy to use;

— tied to level of service.

6.8 Identification of unacceptable impacts

Details of those parts of the wastewater system where the hydraulic, environmental, structural or operational performance does not meet the performance requirements should be recorded.

6.9 Identification of causes of performance deficiencies

Based upon the results of the hydraulic, environmental, structural and operational investigations, the causes of performance deficiencies should be determined. The relative impact and likelihood of a risk event resulting from each cause should be assessed against the utility's risk criteria in order to develop appropriate solutions and to set the priority for action.

7 Planning

7.1 General

The process of planning to fulfil the performance requirements is outlined in Figure 5.

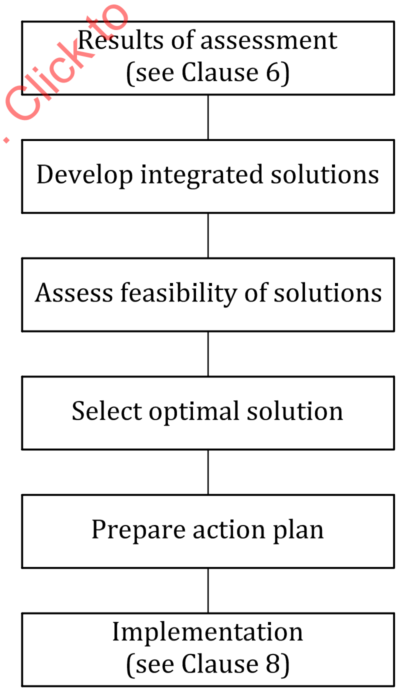


Figure 5 — Process of planning

7.2 Develop integrated solutions

Integrated solutions should be developed that fulfil the performance requirements, taking into account risk considerations and expected future conditions. Various solutions that can be used for planning of rehabilitation are listed in Table 2.

Table 2 — Solution types and options for rehabilitation

Type	Option
Hydraulic	Optimize flow capacity
	Source monitoring and inflow control — reduce the hydraulic input to the treatment plant
	Attenuate peak flows
	Restore or increase treatment plant flow capacity (e.g. by replacing impellers of pumps)
Pollutant control	Optimize pollutant reduction
	Source monitoring and inflow control — reduce the polluting load to the treatment plant
Environmental	Reduce pollutant inputs to wastewater system
	Decrease planned pollutant discharges to receiving water bodies
	Decrease impact by relocation of points of discharge
	Reduce exfiltration by rehabilitation measures
Process	Adjustment of capacities
	Assurance of quality considering new legislative framework
	Optimization of energy use, improvement of efficiency, reduction of CH_4 and CO_2 emission
	Reallocate structures of treatment plants or the wastewater system
	Optimization regarding population development and climate changes
Structural	Protect fabric of tanks by provision of appropriate coatings
	Rehabilitate fabric of structure
Operational	Undertake planned inspection and cleaning of a facility
	Optimize frequency of maintenance of pumps or pumping stations
	Provide additional resilience in the event of future failure (e.g. provision of stand-by equipment or emergency storage)
NOTE This list is not exhaustive.	

The combination of individual options should be integrated into an optimal solution, which can influence the general wastewater masterplan, see 4.2.3 and Annex B, which should then be updated.

7.3 Assess solutions

The proposed solutions can be subject to both internal and external constraints. Internal constraints should involve financial and performance perspectives of the utilities. External constraints (e.g. regulatory or governmental requirements) can take different perspectives (e.g. societal costs and benefits). Both perspectives are governed by financial limitations (current or future) on the availability of funds. For a wastewater utility where available funds could be limited, this also introduces the economic notion of opportunity cost, i.e. if this measure is undertaken, then what other desirable measure(s) might have to be postponed, or not taken within the time horizon. Therefore, the prioritization of solutions, including cost-benefit analysis, should be performed.

Solutions should be assessed and the optimal solution selected with regard to the basic performance requirements and factors to be considered, such as:

a) **Safety in design, construction and operation** — The minimization of risks to health and safety during construction and subsequent operation of the wastewater system.

b) **Social disruption** — The disruption to local residents and other members of the public due to traffic delays, dust, noise and other social factors.

c) **Sustainable use of resources** — The use of energy and other finite resources in the construction and operation of the wastewater system. The ability to recycle materials used in the rehabilitation works, and any waste produced.

d) **Phasing of the works** — The possibility of integrating the solution into a staged programme of works. 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.

e) **Capacity and resource constraints** — The resource constraints (e.g. personnel, supply chain and financial) in the selection and phasing of the options.

f) **Future maintenance liabilities** — The cost of future maintenance works and other operational costs of the wastewater system. The environmental impact of disposal of maintenance residues should also be considered.

g) **Economic appraisal** — The costs and benefits of one solution over another to determine whether their respective net benefits (e.g. from increased asset life) are economically justified.

h) **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; during construction; and during its subsequent decommissioning. All design, construction, investigation, maintenance and operational costs should be taken into account, as well as the indirect costs (e.g. cost of social disruption). When comparing different options, the whole life cost should be calculated over the same period for each option.

7.4 Prepare action plan

The selected integrated solution should be documented to give a single plan for the wastewater treatment plant. The documentation should include:

— detailed objectives;

— legal requirements and permits, including any timescales for improvement;

— performance criteria;

— priorities;

— proposed works including costs and phasing;

— relationship to other construction or planned development;

— consequences for operation and maintenance.

Four types of plan can be prepared:

a) **New development plan**

Where significant new development or redevelopment is proposed in the drainage area, a plan should be produced showing:

— whether the wastewater and/or stormwater from the new development should be drained by extension to an existing wastewater treatment plant or by an independent wastewater system or, for stormwater, by a sustainable drainage and infiltration system;

— if the asset system is an extension of an existing treatment plant, the rehabilitation works to the existing treatment plant to accommodate the additional flows should be described in the rehabilitation plan for that treatment plant;

— whether surface water should be managed by surface water drains and sewers, a system of open channels or by a sustainable drainage and infiltration system;

— the attenuation requirements for surface water management, for example roof greening, on-site ground infiltration;

— an outline of the main sewer systems to serve the development.

b) **Operations and maintenance plan**

The operations plan should include inspection schedules, operational procedures and contingency plans. The operations plan should indicate the approach to be taken in a particular wastewater system. The plan should include:

1) Inspection routines, including which assets are to be inspected and the inspection frequencies, taking into consideration the requirements and importance of each asset, for example:

   i) wastewater treatment plants including screens, sedimentation tanks, aeration tanks, filters, lagoons, sludge treatment facilities, chemical facilities, odour control and outflow facilities including grilles;

   ii) pipelines including inspection chambers, manholes, pipe bridges, above-ground pipelines and outfalls, taking into account the gradient and/or velocity;

   iii) pumping installations, according to potential risk and type of equipment;

   iv) overflows and detention tanks, taking into account storm frequency;

   v) inverted siphons, depending on risk of blockage and potential consequences;

   vi) separators, according to technical requirements;

   vii) grit chambers, gullies, and so on, taking into account storm frequency, capacity and land use;

   viii) relevant equipment of the treatment plant such as pumps, buildings, grit chamber, screens, compressors and electrical equipment.

2) Procedures for the operation of the components of the wastewater system:

   i) operation of wastewater treatment plants;

   ii) operation of pumping stations;

   iii) operation of any special components (e.g. vacuum or pressure installations within the asset system);

   iv) setting dam boards, valves and weirs;

   v) operation of detention tanks;

   vi) assignment of responsibilities for carrying out procedures.

Maintenance plans should be based on maintenance schedules for each asset of the system including a cleaning plan, a pest control plan, and an electrical and mechanical equipment maintenance plan. These maintenance plans should consider:

3) The type of maintenance strategy to be used in each asset of the system and the monitoring requirements and frequencies and related risk assessments which take into account the probability of failure and its consequences. The strategies for maintaining treatment facilities are planned or reactive maintenance, or a combination of both:

   i) Planned maintenance includes a program of work to remedy the defects and problems identified during inspection. Priority should be given to assets where the consequences of failure are severe.

ii) Reactive maintenance involves responding to failures and problems as they are identified. It is appropriate for those parts of the wastewater system that can function with little or no maintenance or where the consequences of failure are low.

c) **Rehabilitation plan**

Rehabilitation includes a wide range of activities to restore or upgrade the performance of a wastewater system, including those examples shown in Table 3.

Table 3 — Scope of a rehabilitation plan

	Examples of system-related measures	Examples of asset-related measures
Restore original performance	— Remove extraneous flows	— Cleaning — Repair — Renovation — Replacement (like for like)
Upgrade original performance	— Maximize use of existing flow capacity — Reduce hydraulic input to the wastewater treatment plant — Attenuate peak flows	— Replacement (increased or decreased flow)

The rehabilitation plan should include information on proposed rehabilitation works. The options to be considered fall into one or more of the four categories: hydraulic, environmental, structural and operational performance. The works necessary to upgrade an existing wastewater treatment plant and pumping station to meet the performance requirements should be incorporated into a rehabilitation plan. This should include:

a) details of the necessary upgrading works;

b) other options for upgrading the treatment plant and pumping station;

c) any anticipated phasing of the work;

d) whether any of the items are conditional on any planned developments.

Rehabilitation includes a plan of work to remedy the defects and problems identified during investigation

d) **Contingency and emergency plan**

Contingency and emergency planning is the process of setting out procedures to be used in case of crisis, for example significant breakdown of a part of the wastewater system. Effective contingency and emergency plans should aim at restoring functional requirements in accordance with previously agreed priorities (see 4.1.2, Table 1). They should also include procedures for dealing with major failures and other emergencies resulting from the risk considerations, such as:

— accidental spillages of toxic, noxious or explosive substances;

— discharge of special substances used in firefighting;

— failure of pumping stations or (pre-)treatment facilities;

— flooding due to an exceptional rainfall event;

— effect of other forms of flooding on the wastewater system.

Contingency and emergency planning should in particular guide the allocation and prioritization of resources. Examples include investments in monitoring devices, emergency plant and system resilience. Knowledge gained from past crises should also be taken into account for future strategic planning and adjustment of operation and maintenance planning.

8 Implementation

8.1 Introduction

The implementation plan should take into consideration the financial risk(s) to the wastewater utility based on the principle of the "plan-do-check-act" (PDCA) approach (see Figure 6):

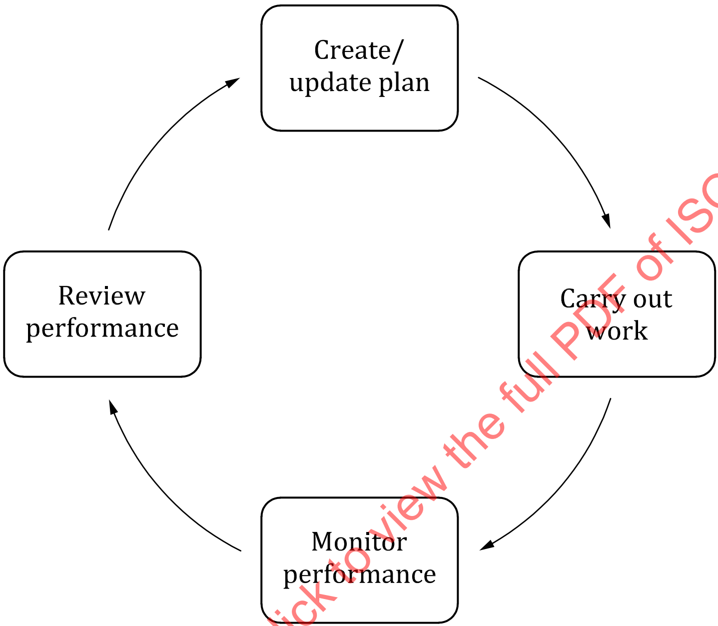


Figure 6 — Process for implementation following the PDCA approach

8.2 Create/update plan

For maintaining or improving the performance of the asset system, the objectives and functional requirements should firstly be established followed by the technical processes to investigate, assess and create maintenance, rehabilitation and operational plans to maintain or improve the performance of the asset system.

Necessary works to rehabilitate, maintain and operate the wastewater treatment plant should be defined in the rehabilitation, maintenance and operational plans.

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

8.3 Carry out work

In the context of management of assets for extending, reducing or rehabilitating a wastewater treatment plant, the following should be considered:

— selection of appropriate technologies and materials;

— selection of a contractor appropriately experienced in the use of the technologies and materials;

— quality control of materials (specification and procurement);

— quality of installation and conformity with installation requirements;

— evaluation of the process performance of each asset.

8.4 Monitor performance

It is important to monitor the effectiveness of solutions, including the records (inventory) and the process and hydraulic model or process engineering simulation model using performance indicators.

Monitoring data should be identified and captured. That is specifically relevant to identifying the extent to which performance indicators are attained in meeting the committed level of service. Only this specific data should be captured to minimize the effort of management of assets.

8.5 Review performance

The performance requirements should be reviewed periodically.

The monitoring data captured should be reviewed to identify the extent to which key performance indicators are attained to meet the committed level of service.

9 Operation and maintenance

9.1 General

The purpose of operation and maintenance is to ensure that the wastewater treatment plant performs in accordance with the functional requirements defined in Clause 4 and in accordance with any operation and maintenance plan.

Operation and maintenance should ensure that:

— the entire wastewater system is operationally ready at all times and functions within the performance requirements;

— the operation of the treatment plant is safe, environmentally acceptable and economically efficient;

— as far as possible the failure of one facility of the wastewater treatment plant does not adversely affect the performance of the other parts.

Examples of the difference between the terms operation and maintenance are shown in Table 4.

Table 4 — Difference between the terms operation and maintenance

Term	Retain original performance (routine activities)	Restore original performance	Upgrade performance	Examples
Operation	Yes	No	No	Monitoring, regulation of wastewater flow, operation of pumps, ventilation, valves and other equipment
Maintenance	Yes	Yes	No	Cleaning tanks, adjusting metering equipment, lubrication of a pump or valve; replacement e.g. of electromechanical equipment or SCADA; repair of a pipe, pump or valve

Effective operation and maintenance of a wastewater treatment plant are important elements for the management of assets to keep the condition of the assets in their required states and provide for a long service life for each asset. The operation and maintenance of a wastewater treatment plant depend on, for example:

— planning;

— sufficient numbers of competent personnel;

— clear assignment of responsibilities;

— suitable equipment;

— knowledge of the wastewater system, its operational assets and the users connected;

— adequate records and analysis.

There can also be requirements relating to the resolution of performance deficiencies, for example to remedy failures and problems within acceptable timescales.

Flexibility of operation of the wastewater treatment plant, i.e. its ability to function when a section of it is taken out of service for maintenance or rehabilitation, is usually dependent on its design and existing features such as flow recirculation or flow-path duplication. However, if such features are not present or are insufficient, other measures (e.g. temporary bypasses) should be implemented to avoid performance interruptions.

9.2 Operation

The purpose of operation is to ensure that the wastewater treatment plant performs in accordance with its functional requirements and in accordance with any operation plan.

Operation should ensure that the aim of the wastewater utility to successfully deliver the treatment of wastewater in the required quantity and quality can be achieved at all times. This is achieved if the functional requirements of the operation and maintenance plans are met (see also 4.1.2) and the necessary resources for this purpose are available (e.g. funds, expertise, personnel).

Operation includes:

— controlling tanks, filters, pumps, dosing and other equipment;

— assuring and monitoring the processes of treatment, pumping and discharge;

— using retention and detention tanks;

— acting in accordance with contingency, emergency and safety plans;

— regularly inspecting and documenting;

— measuring water and sludge quality;

— monitoring and controlling flow and wastewater and sludge quality;

— pest control;

— processing complaints.

Urgent interventions that are generally intended to be temporary are included in operation.

9.3 Maintenance

The purpose of maintenance is to ensure that the wastewater treatment plant performs in accordance with its functional requirements and in accordance with any maintenance plan. Well executed maintenance will also contribute to optimization of assets' operational lives and risk mitigation.

Maintenance includes:

— pursuing 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;

— local repair or local replacement of damaged pumps, motors, valves or other equipment including their accessories in order to maintain their functioning and safeguards;

— maintenance of mechanical and electrical/electronic equipment;

— regular attention to accessories like valves, dosing, control and metering equipment.

A generally applicable maintenance strategy for all equipment cannot be stated. A risk analysis of the assets leads to information on selection of an appropriate maintenance strategy, from the alternatives available, which takes into account costs and the probability of successfully achieving the intended benefits. This is consistent with the "reliability-centred maintenance" (RCM) approach. This concept focuses on the reliability of a subject matter and aims to reduce the maintenance costs while optimizing the reliability.

The goal is achieved through an analysis of each subject matter, which is based on the following questions:

— Does the subject matter conform with function (performance)?

— Which disorder or failure can impair the function?

— What caused the error?

— What is the effect due to the disorder or failure?

— How can the disorder or failure be predicted or even avoided?

— What can be done if the disorder or failure cannot be predicted or avoided?

From the assessment of the answers to these questions the proper strategy can be derived approximately, leaving a degree of discretion on each subject matter.

When assessing the impact of disorder or failure upon an asset, consideration should be given to the wider impact upon the wastewater treatment plant because of the composite nature of the asset within the wastewater treatment plant.

A brief overview of the alternative maintenance strategies available is given in Table 5.

Table 5 — Overview of maintenance strategies

Maintenance strategy	Brief description	Advantages	Disadvantages
Incident-based maintenance	— No action, to determine the actual state of the asset/ system — Only failure-based repair or replacement	— The service life of the asset is completely exploited — Low costs for inspection and documentation	— Unpredictable occurrence of failure — Consequential failures are possible, which leads to uneconomical repair — 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
Preventive maintenance	— Few measures are taken for condition assessment — The preservation of the nominal condition of the assets is performed by preventative replacement of wear and tear parts	— Low unplanned failure probability — Predictable decommissioning	— High cost by low utilization of service life — High downtime caused by repair
Condition-based maintenance	— If the condition of the asset is regularly identified by inspection, the wear and tear is defined as the limit deviation in regard to the nominal performance — Risk-based maintenance is included	— Low unplanned failure probability — Predictable decommissioning — Optimal utilization of the service life	— Higher costs for the determination of condition — Higher qualification of the staff
Predictive maintenance	— Besides the determination of the condition, it is also intended to improve the asset and to reduce the wear and tear	— The availability of the complete asset system increases — Long term the expenses for maintenance decrease	— High costs for troubleshooting — Very high qualification for the staff

10 Rehabilitation

10.1 General

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

Once a wastewater treatment plant is installed and operated, the highest expenditure of cost over its life cycle is determined by the consumption of resources. These include energy, dosing agents, disposal of residuals and personnel expenses for operation and maintenance plus decision making concerning the rehabilitation of the wastewater treatment plant. If the cost of maintenance and operation of the facilities increases beyond what is reasonable, or the quality of the wastewater or the legal requirements for treated wastewater change, the rehabilitation of assets or parts of the wastewater system can become necessary.

The time for rehabilitation is thus determined by the life-cycle costs of the asset portfolio. Strategic and tactical plans form the basis of the further procedure.

Therefore, a sustainable process for managing wastewater assets should be subdivided into the three logical steps that build upon each other so as to be able to identify and assess, also by way of comparison, the short-, medium- and long-term impact of rehabilitation[12], (see 4.4.3, Figure 3):

a) determining a long-term rehabilitation strategy;

b) drafting a medium-term rehabilitation tactic;

c) implementing operational rehabilitation measures required in the short term.

Determining a strategy starts by identifying the scope of rehabilitation works required and the pertinent budget on the basis of a long-term perspective so as to obtain and/or maintain adequate wastewater system condition and the resulting level of service. The tactic includes identifying and defining the sequence of rehabilitation measures required in the medium term and pre-selecting the rehabilitation technologies and materials. The operational level includes reviewing the actual execution of the rehabilitation work and taking into account possible alternative options.

Shorter periods of review require more intense work on, and higher degrees of, detailing of the respective sub-processes, entailing a higher total expenditure in terms of both time and cost. More precise details render the necessary rehabilitation measures more concrete. The results of the individual logical steps should be synchronised with one another.

10.2 Strategic plan for rehabilitation of physical infrastructure (long-term planning)

10.2.1 General

A rehabilitation strategy should be worked out for the entire drainage area and the wastewater treatment plant(s). In larger plants it can be necessary to develop specific strategies for single facilities within a plant. The rehabilitation strategy should consider all assets of the wastewater system and their interaction.

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. Any subsequent review should be sufficiently frequent to address developments affecting the wastewater system (see 10.1). Function, condition and operation of all assets of the wastewater system should be considered in setting the review period.

Important indications for a rehabilitation plan are the findings of maintenance and operation of the assets.

Usually, single units in function groups (i.e. exercising their function in the aggregate) should be combined and then undergo a joint rehabilitation of the whole functional unit largely to take advantage of a corresponding improvement potential.

As an example this can involve subdividing the treatment plant into the following major asset types:

— inlet screens;

— grit chambers;

— primary settlement tanks;

— aeration tanks;

— secondary settlement tanks;

— sludge treatment (e.g. conditioning tanks, dewatering, digestion, incineration);

— other installations (e.g. electrical and mechanical equipment).

Depending on the available data and following an analysis of the existing asset system, its assets within major asset types should be broken down further, for example by:

— intake assets;

— the relevant treatment process including the respective facilities;

— pumping stations;

— equipment for general electrical supply (transformers, high, medium and low voltage switchgear);

— control equipment and automation technology;

— data transmission and supervision systems;

— metering technology;

— emergency power systems;

— buildings, properties, fences, supervision systems, security systems;

— asset types of comparable location and installation conditions;

— asset types of comparable modes of operation and/or conditions of use.

Certain areas or asset types exhibiting unusual or exceptional underperformance, quality problems, exceptionally high operating costs or frequency of disorder that have a major impact on the rehabilitation strategy should be broken down accordingly into asset sub-types with advanced differentiation.

The rehabilitation need of the wastewater treatment plant or its facilities under review is determined on the basis of the data and findings identified for the individual asset types.

Typically, the rehabilitation strategy varies between different major asset types depending on maintenance strategy and risk assessment.

10.2.2 Strategic approaches

A number of different approaches are possible for the formulation of the strategic plan on rehabilitation. These approaches can be combined to achieve the optimal strategy for a wastewater system. Different approaches can be suitable for different parts of the wastewater system, depending on local conditions and the risk attached to consequences of failure. Service life can be simply estimated by age as a first step. The statistical estimation can be used to understand future rehabilitation needs if the ageing deterioration was recognized in the inspection. When investigation results have been accumulated and assessed, it is advisable to improve the level of estimation.

Possible approaches include:

a) **Asset value approach** — A financial-based approach that is used to ensure that rehabilitation is carried out at a rate that ensures that the value of the wastewater treatment plant at the end of a specified period does not fall below a specified threshold.

b) **Asset-type-related approach** — One part of the assets of a wastewater treatment plant is selected with common characteristics, requirements and properties, for example: a pumping station, a treatment step, a monitoring system.

c) **Condition-based approach** — All components of a wastewater treatment plant are inspected and those that do not meet some specified threshold condition are rehabilitated. If all components cannot be inspected in a short period, a sampling survey and a screening method can be used.

d) **Functional-related approach** — This is built around the need for changes to improve the performance of the wastewater system (e.g. the need to reduce or eliminate discharges to receiving water bodies; to improve seismic resistance) and takes the opportunity to do other rehabilitation work where this can be done more efficiently at the same time.

e) **Reactive approach** — This involves responding to failures and problems as they are identified. Examples can include restoring structural integrity.

These strategic approaches, including their advantages and disadvantages, are shown in Table 6.

Table 6 — Advantages and disadvantages of different strategic approaches

Approach	Advantages	Disadvantages
Asset-value approach	— the changes in asset value of the wastewater system can be made transparent — suitable for determining a fixed-rate budget	— it is solely financially driven — needs to be used in combination with other approaches
Asset type-related approach	— it is easy to get a clearer view of the work and the benefits — it is possible to carry out the work in a defined period — concentration of work on one asset type can be financially efficient — relevant asset types within the wastewater system are comprehensively rehabilitated	— a detailed cost estimate can only be made after detailed investigation of the area — problems remain for other asset types of the wastewater system for a longer period
Condition-based approach	— status of all assets known by inspection — reduction in need for reactive rehabilitation — very efficient way of rehabilitation by selecting only assets with high priority — the complete treatment system is maintained to a defined standard	— problems with a lower priority remain in the wastewater system for a longer period — loss of efficiency by the possible need to carry out further works in the same parts of the wastewater system at a later time
Functional-related approach	— future-oriented planning creates capacity, alleviating problems before they occur	— cannot be applied as sole approach
Reactive approach	— can be cost-effective where consequence of failure is low	— cannot prevent failures occurring — can only be safely based on a risk-based approach
Risk-based approach	— optimal risk-cost ratio — bundling of works to optimize time and manpower costs	— can lead to deficiencies of water/sludge quality, breakdowns or service interruptions (if risks are not managed safely)

The reactive rehabilitation approach should only be used where the risk of failure is considered acceptable, taking into account both the probability of failure and the consequence.

10.2.3 Budgeting

The rehabilitation budget required is generally determined by the rehabilitation plan. Cost estimates should be based on utility-specific, long-term empirical data as well as on any planned assets and treatment systems. The results of possible strategic system optimization activities should likewise be included in the rehabilitation budget calculation.

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

The future plans for rehabilitation work for the whole treatment plant should be estimated. Introduction of maintenance to extend the service life of treatment plants reduces life-cycle cost and spreads the levels of the rehabilitation cost across the years to an extent balanced with strategic proactive capital improvements.

10.3 Tactical plan for rehabilitation of physical infrastructure (mid-term planning)

10.3.1 Risk-based approach to evaluation of priorities

The tactical plan for rehabilitation pursues the objective of implementing within the medium term, for example within two to five years, the amount of rehabilitation determined by the rehabilitation strategy for the individual asset types. The operational rehabilitation plan required for the task should be identified and prioritised.

Rehabilitation needs should be determined according to standard lifespans or consideration of other requirements (e.g. due to changed structural design codes or legislative requirements regarding effluent water quality or sludge treatment).

The prioritization of measures for various parts of the wastewater treatment plant or even the whole wastewater system (e.g. wastewater networks, pumping stations, treatment plants, retention and detention tanks, sludge treatment facilities, IT infrastructure) including asset types is difficult and cannot be easily compared. The prioritization criteria should be made as objective as possible.

The criteria for prioritization should be based on the risk emanating from an asset or affecting its function. This risk results from the likelihood of occurrence and the consequence of failure. Health risks are of particular importance for all stakeholders. A key concern for the wastewater utility/operator/responsible body, in addition to the costs of loss, can be the avoidance of reputational damage.

The wastewater utility should define utility-specific risk-assessment criteria that support a risk-evaluation approach and are capable of producing risk-evaluation results for each facility.

The risk-assessment process firstly requires 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).

Risk-assessment criteria can be subdivided into the following groups:

a) The probability of failure occurrence can be deduced from:

   1) the failure development in a component (individually or in aggregate);

   2) the failure development in the asset type (failure and/or empirical data);

   3) characteristics of individual assets;

   4) other condition data of machinery or technical facilities (e.g. corrosion, cavitation, loss of efficiency);

   5) knowledge about fluctuation of level of service.

b) The probability of occurrence of impairments can be deduced from:

   1) operational experience;

   2) measured values;

   3) calculations;

4) user complaints.

c) The extent of failure or disorder can be assessed in relation to, for example:

1) hazards to

i) persons;

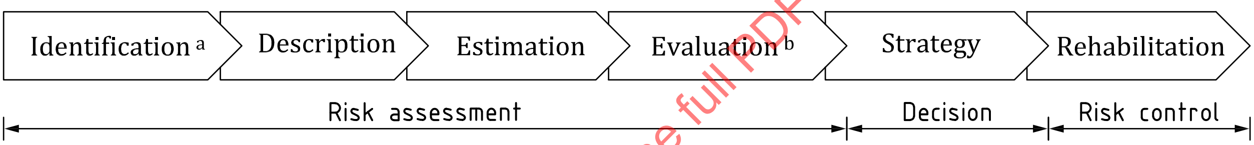
ii) assets (tangible and intangible);

iii) environment;

2) a wastewater utility's image/public perception.

Having identified, described and analysed each risk using a consistent set of risk-analysis criteria, a wastewater utility should then evaluate the relative significance of each risk compared with the others based on a consistent set of evaluation criteria. Evaluation results serve to assess the risk for each asset on the basis of predefined criteria. The evaluation results for the entire wastewater treatment plant or for individual components should determine the rehabilitation priority ranking of the assets concerned. Risk can be expressed by a variety of units.

Figure 7 illustrates the risk-assessment process leading to the evaluation of the priority of assets for rehabilitation.



a Of each risk individually.

b Of all risks relative to one another.

Figure 7 — Process of risk assessment, decision making and risk control

10.3.2 Individual risk evaluation and prioritising for risk control

A risk-assessment process (4.3) should be defined and documented that contains the relevant criteria for the relative evaluation of the risks. Application of the process will produce data, for example in the form of points scored, with serious risks scoring more points. The process should determine how the risk assessment should be applied to assets and asset types with both similar and dissimilar characteristics.

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 then yields the competing priority ranking of the rehabilitation measures planned for the medium term.

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 documented and should be considered in the evaluation process. The absence of information should not be a reason for excluding a risk from the evaluation process.

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:

— unambiguous identification of an asset (technical data);