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MANUAL 1

Integrated planning of urban water services: a global approach

Helena Alegre / Dídia Covas

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Introduction

Global framework, key principles and concepts and the main challenges and opportunities.

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1.1 Scope

The scope of this TRUST series of best practice manuals is the integrated planning of urban water services, focusing on **Infrastructure Asset Management (IAM)**. IAM aims at ensuring that infrastructures are managed in such a way that sustainability of the service is ensured by maximizing service performance at a minimum cost and with acceptable risk levels, in the long term. Urban water services include water supply and wastewater and storm water management.

This manual introduces a global framework, key principles and concepts and the main challenges and opportunities.

This is Volume I of a series of manuals developed in scope of the TRUST project (www.trust-i.net). The other volumes include specific guidelines for policy-making at a national or regional level (Manual 2) and for strategic and tactical planning at the utility level (Manuals 3 and 4) as well as a portofolio of rehabilitation techniques used in supply pipes and storage tanks and drainage systems (Manuals 5 and 6).

1.2 Document structure

The document has six chapters, being the first the present introductory chapter.

Chapter 2 explains why integrated planning of urban water systems is crucial for ensuring the sustainability of the service, referring the main drivers, gaps, consequences and existing international standards.

Chapter 3 explains that urban water services evolve over time as living bodies, with their own metabolism which needs to be understood in order to be adequately managed, and presents the main concepts and general principles of metabolism analysis.

The global framework of integrated planning is presented in **Chapter 4**, including planning levels and associated processes, scope, time horizons, and dimensions to be taken into consideration.

Chapter 5 highlights the main technological challenges and opportunities in urban water systems.

The last chapter (**Chapter 6**) synthetises the key-messages of the current manual. The document should be sequentially read for a better understanding of the principles and concepts and for the reader gradually getting familiar with the subject.

1.3 Target public

This manual is targeted for two groups of public: policy makers and water professionals as follows (Cabrera *et al.*, 2011):

TARGET GROUP	PROFILE	NEEDS AND EXPECTATIONS
Policy makers	Local and national governments, European committees, water authorities, and planning institutions No technical formation expected	Expect solutions to improve water management and society's needs Succinct deliverables with very plain conclusions
Water professionals: Technical staff	Control all the technical aspects of urban water systems other than management Technical formation to be expected Close profile to the scientific community	Expect technical content with details for practical uses Particularly technical documents; no research details necessary
Water professionals: Decision makers	Responsible for planning and leading the work of a group of individuals and supervising their work Technical knowledge expected Close profile to policy makers	Expect executive material Short content with clear conclusions

2 The importance of integrated planning for the sustainability of urban water services

2.1 Integrated planning is key for efficient use of financial resources

Policy-makers are often faced with the need for deciding where to allocate limited financial resources, trying to maximize the benefit for the society. Each service provider in a societal sector tends to argue in favour of their direct interest, and the decision makers need to assess the overall advantages and disadvantages of each option in order to establish priorities and support their decision. Gains in efficiency in one sector result in financial savings that can be reinvested in the same or in another sector. A structured approach to infrastructure asset management provides a framework that brings transparency and accountability to these processes, and, above all, enables a much more efficient use of financial resources.

"A structured approach to infrastructure asset management provides a framework that brings transparency and accountability and enables a much more efficient use of financial resources."

With the current know-how, provision of urban water services is based on expensive and long lasting built assets, such as pipes and sewers, pumping stations, storage tanks and other civil engineering works. In order to keep the true value of the existing assets, there is the need to spend in capital maintenance the corresponding to the annual depreciation of these assets, on average of the order of 2% of the infrastructure replacements cost. This corresponds to a much higher ratio between the capital maintenance costs and the total activity costs than needed for most other public services, such as schools, health care, transportation of passengers, electricity or telecommunications. Any gains in efficiency will therefore have major financial impacts. Solutions implemented and investments made today in urban water infrastructures always have a long term effect of many decades.

Additionally, urban water services have a major impact on societal behavior and well-being, particularly in terms of public health, comfort and economy. This implies that these services are provided on a permanent basis and with a quality that meets the users' needs and expectations, at present and throughout the future.

2.2 Managing asset value in the long term

Given the high construction costs and the long term effects of urban water assets, the selection of the best alternative solutions need to be assessed and compared taking into account all relevant effects (costs, performance and risk) during their entire life, which may range from a few years to many decades.

Ok, I got it!...
Thus, I shall adopt infrastructure whole life costing in my analysis, right?

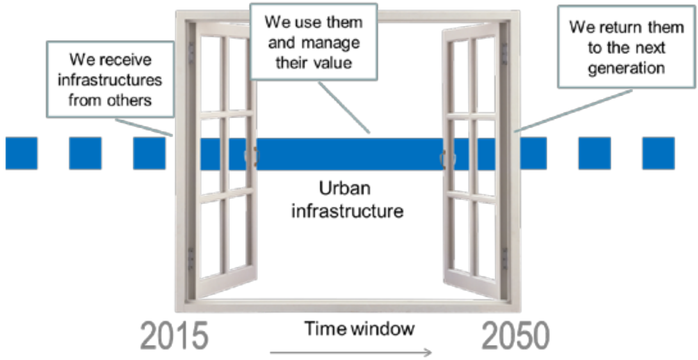
Further explanation:

“Mind you are dealing with an infrastructure that has a system behaviour. Neither every asset, the system is composed of, is new at the beginning of the analysis, nor asset life-time is the same for all assets. The solution is to adopt an analyses period not less than 15-20 years, preferably longer. Ideally it should be of the order of magnitude of the longest life time assets (50 to 100 years). However, uncertainty about future scenario is often very high, and utilities tend to adopt shorter periods of analysis, for which forecasts are less uncertain. “

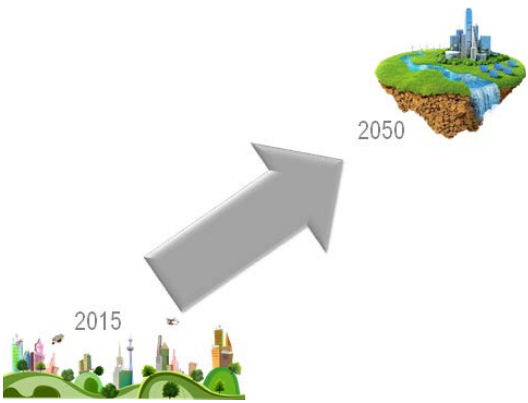
Public services provided by urban water infrastructures do not have a finite time span. Therefore, public infrastructures should have indefinite lives. IAM aims at assisting decision-making in short and medium term that maximize the overall benefits of the use of the existing infrastructure, while managing its value. This should be based on analyses in a long term time window, in order to ensure that the service is not put at risk for the coming generations.

> “Infrastructure assets have indefinite lives. Economic lives, however, can be assigned to individual components of an infrastructure system.”
>
> Burns *et al.* (1999)

Urban water infrastructures have indefinite lives. They need to be managed in a long term time window

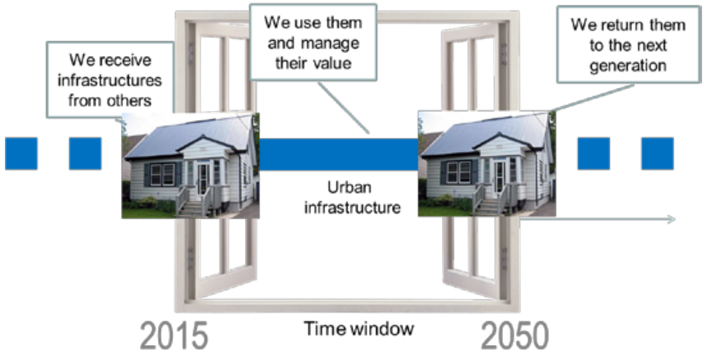


Where to be in 2050? Transition has to be managed.

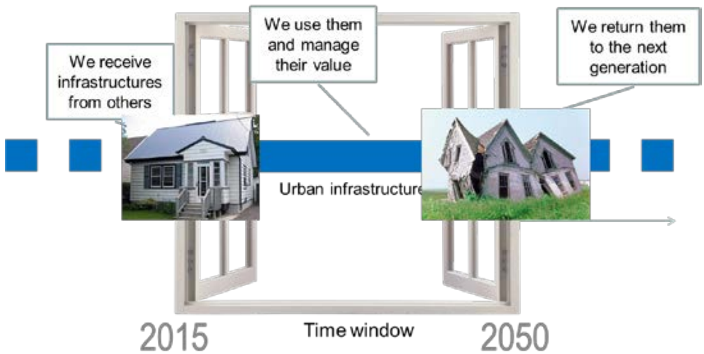


Starting with an infrastructure in a given condition and with a given performance. Several long term managment options can be taken.

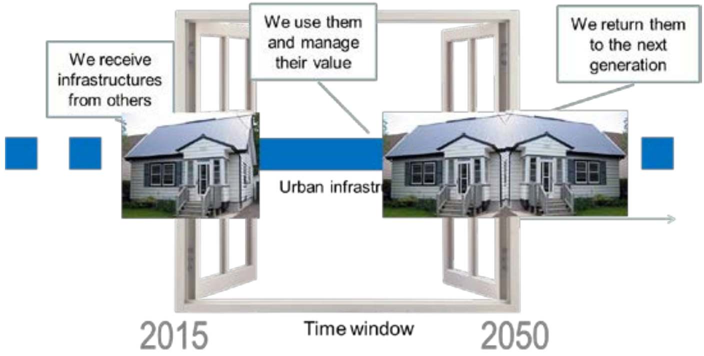
One option is to return it to the next generation as it was inherited...



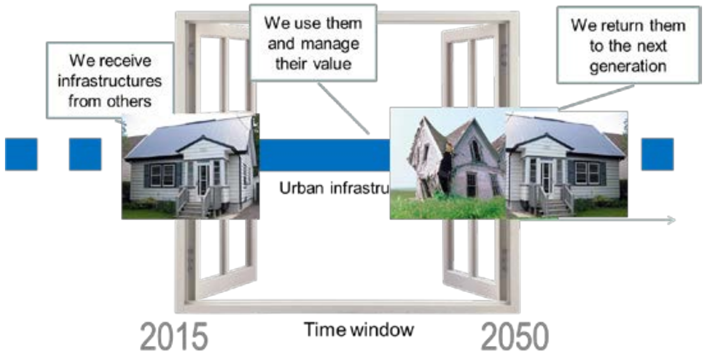
It can be used, but neither changed nor maintained in an appropriate way



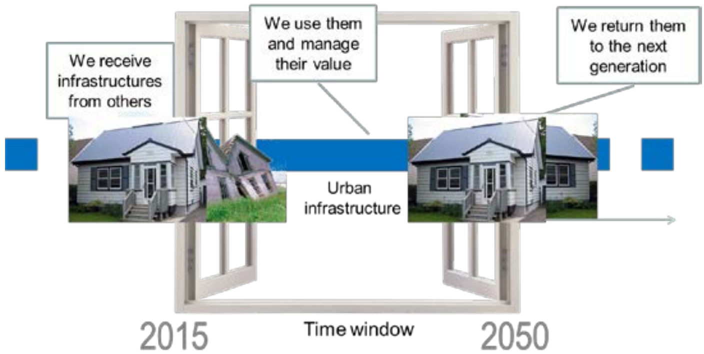
Another option is to expand and duly maintain the infrastructure.



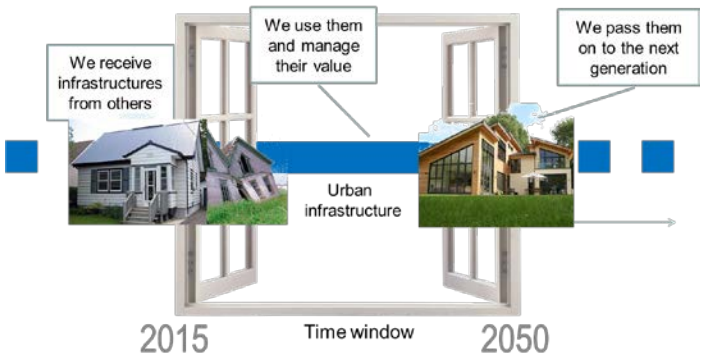
The infrastructure can be expanded as needed, but inherited assets can be insufficiently maintained.



The infrastructure can be expanded as need, but inherited assets can be sufficiently maintained.



The infrastructure can be expanded as needed and inherited assets can be rehabilitated



The long-term effect of investments and the criticality of water services for the society have led to rather conservative solutions, because decision-makers fear out-of-the-box or disruptive system designs and technologies.

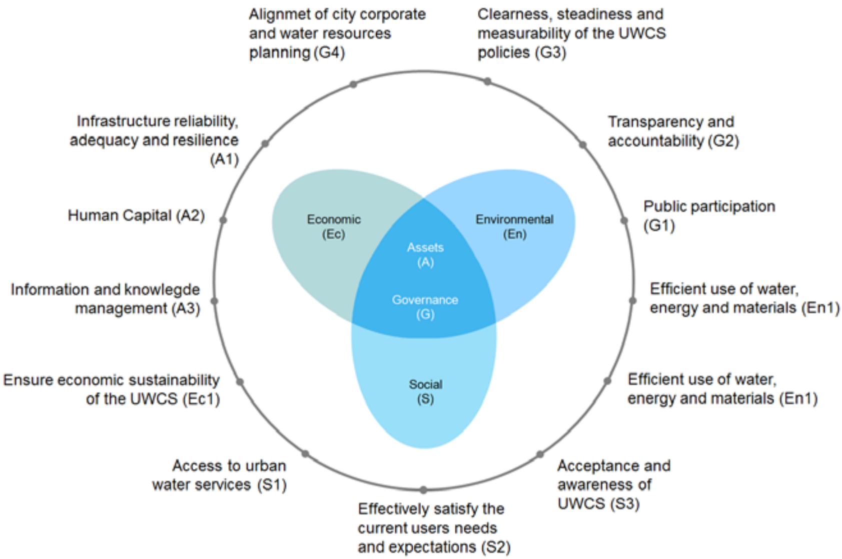
Traditional solutions tend to be well-proven in many regards. However, business as usual is not an option, given the economic, social and environmental pressures: current infrastructural and operational solutions are often inefficient in economic, energy or water resources terms, and insufficiently effective to cope with an increasingly challenging world.

Consequently, most current urban water services are not sustainable!

2.3 Sustainability in urban water cycle services

Sustainability in urban water cycle services (UWCS) is met when the quality of assets and governance of the services is sufficient to actively secure the water sector's needed contributions to urban social, environmental and economic development in a way that meets the needs of the present without compromising the ability of future generations to meet their own needs (Brattebø *et al.*, 2013).

TRUST approach to sustainability assessment



To achieve sustainable urban water services it is essential:

- To have a long term vision of the service.
- To ensure that service objectives and targets are permanently met in the transition path from the present situation until the long-term vision is fulfilled.
- To take into account all dimensions of sustainability above mentioned.

Objective-oriented strategic planning with a long term time horizon and a broad scope, covering the whole service area and involving all relevant stakeholders, is therefore needed.

The TRUST framework for sustainability establishes key objectives of the urban water services and corresponding assessment criteria for each sustainability dimension, aiming at a transparent, valid and holistic method for target definition and assessing results. However, decision-makers should customize these objectives and criteria taking into account their own vision and context.

The assessment method should be inclusive and flexible with respect to stakeholder involvement and decisions regarding target setting and trade-off as part of a multi-criteria decision analysis process. The assessment is made operational by critically and carefully examining a chosen set of performance metrics and how they comply with a predefined set of sustainability objectives and criteria. The performance metrics/indicators may be quantitative and/or qualitative, and are specifically chosen in order to take account of the particular context and challenges of a given urban water cycle system, in a medium- and long-term transition context.

Objectives and criteria of the UWCS sustainability dimensions (Brattebø et al., 2013).

DIMENSION	OBJECTIVES	ASSESSMENT CRITERIA
Social	S1) Access to urban water services S2) Effectively satisfy the current users' needs and expectations S3) Acceptance and awareness	S11) Service coverage S21) Quality of service S22) Safety and health S31) Affordability
Environment	En1) Efficient use of water, energy and materials En2) Minimisation of other environmental impacts	En11) Efficiency in the use of water (including final uses) En12) Efficiency in the use of energy En13) Efficiency in the use of materials En21) Environmental efficiency (resource exploitation and life cycle emissions to water, air and soil)
Economic	Ec1) Ensure economic sustainability of the UWCS	Ec11) Cost recovery and reinvestment in UWCS Ec12) Economic efficiency Ec13) Leverage (degree of indebtedness) Ec14) Willingness to pay
Governance	G1) Public participation G2) Transparency and accountability G3) Clearness, steadiness and measurability of the UWCS policies G4) Alignment of city, corporate and water resources planning	G11) Participation initiatives G21) Availability of information and public disclosure G22) Availability of mechanisms of accountability G31) Clearness, steadiness, ambitiousness and measurability of policies G41) Degree of alignment of city, corporate and water resources planning
Assets	A1) Infrastructure reliability, adequacy and resilience A2) Human capital A3) Information and knowledge management	A11) Adequacy of the rehabilitation rate A12) Reliability and failures A13) Adequate infrastructural capacity A14) Adaptability to changes (e.g. climate change Adaptation) A21) Adequacy of training, capacity building and knowledge transfer A31) Quality of the information and of the knowledge management system

Urban water systems planning tends to come downstream in the overall city planning process, responding to the needs identified in the urban master plans, in a reactive mode.

However, to be sustainable, urban water systems (i.e., water supply, wastewater and storm water) must be designed and implemented in conjunction, and upstream in the city planning process together with other public infrastructures, in a true integrated planning approach.

For instance, the feasibility and success of using alternative water sources or decentralized systems depends on a good integration in the city organization, in terms of urban planning and of governance (i.e., relations between utilities providing each service, and between utilities and stakeholders).

Integrated planning shall also take into account the different levels of policy and decision making. Countries and regions may have strategic plans relevant for the urban water services, which will directly influence the urban water utilities' own planning. There is a clear need for coordination between them.

In this series of manuals, other volumes will present guidelines for policy–makers as well as guidelines for strategic planning and road-mapping and for tactical planning at the utility level.

Alignment and feedback procedures between the various planning levels should be implemented.

2.4 Integrated planning of urban water services

Integrated planning of urban water services is the process of defining and implementing coherent solutions and transition paths that lead to sustainable urban water services.

This requires several levels of detail, from long-term to short-term, and from national or regional to local level, in an aligned way. It should take into account not only the economic, social and environmental aspects of sustainability, but also governance of the services and the quality of the human, information and knowledge, and infrastructure assets.

Why is IAM critical within the integrated planning?

3

3.1 Playing with figures

Consider a water distribution network with an average age of 40 years and with an annual rehabilitation rate is 0.5%. A higher rehabilitation rate has not been adopted as it would result into higher water tariffs and the investment priority has been given to the expansion of the network to new urban areas. Local utility experts consider that the average useful life for the predominant pipe materials is 50 years. This is simplified example of a common situation in many utilities in the world.

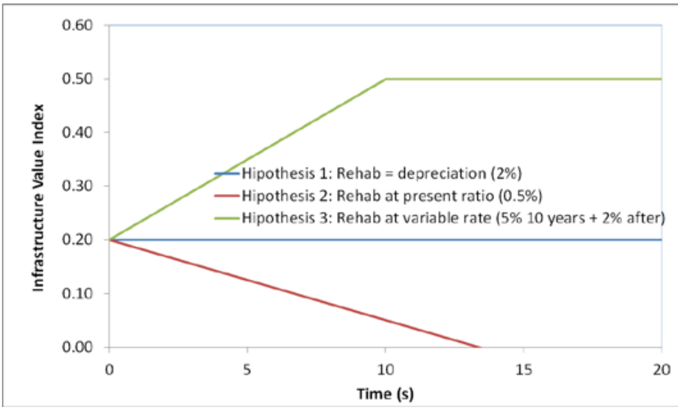
For the current annual rehabilitation rate of 0.5% to be sustainable, pipes would need to last at least 200 years, which is not realistic. Assuming the life expectancy of 50 years and current pipes age of 40 years, within 14 years the utility will not be able to provide any service to its users.
The accumulated capital maintenance deficit will have negative impact on the future generations and cannot be easily compensated with periods of high rehabilitation rates. First, it leads to a decrease of the quality of service in the medium and

long term. Second, it postpones the need for rehabilitation investments that, sooner or later, will have to be carried out in a more concentrated way and that will result in the inevitable increase of tariffs. Finally, the construction works associated to very high rehabilitation rates have a negative impact to the living conditions in the city.

For the current situation, the percentage of residual life of pipes is 20%. In a well-maintained mature infrastructure it should be of the order of 50%.

If the annual rehabilitation rate of 2%, equal to the depreciation rate of the infrastructure (i.e., inverse of the useful life), is adopted, the percentage of residual life of pipes would continue to be 20%.

To reach the ideal percentage of residual life of pipes of 50% in 10 years, a rehabilitation rate of 5% would be needed during that period followed by a 2% rehabilitation rate from then on to maintain the index.



Needless to say, reality is much more complex than this example. However, this illustrative case shows that lack of capital maintenance in due time may lead to a very significant decrease of service quality, if not to the complete service failure in the near future.

This example aims at bringing the attention for the need of adopting long term time horizons for the strategic management of urban water systems. If strategic plans have a short time horizon (3-5 years), as it often occurs in practice, the effect of having a low rehabilitation rate does not become evident on the quality of service and leads to a significant decrease in the annual total costs.

Therefore, in a short term analysis the easiest way to improve economic efficiency, which is increasingly a driver of any utility CEO and of service regulators, is to minimize capital maintenance (i.e., to adopt low rehabilitation rates). Consequently, many world water infrastructures are aging and losing their value, providing services that, in the long run, will inevitably have a low quality and efficiency, i.e., unsustainable services.

If a long term time horizon is considered in the strategic planning (e.g., 30-50 years), the need for sustainable rehabilitation rates becomes evident.

3.2 Partial views of IAM

Infrastructure asset management (IAM) is most often approached based on partial views:

> “IAM means financial planning and the control of business risk exposure.”
>
> Business managers and accountants

> “IAM is focused on network analysis and system design, master planning, construction, optimal operation and hydraulic reliability.”
>
> Water Engineers

> “The infrastructure is mostly an inventory of individual assets and IAM tends to be the sum of asset-by-asset plans, established based on condition and criticality assessment.”
>
> Asset maintenance managers

> "IAM tends to be driven by service coverage, quality and affordability in the short run, since water infrastructures are mostly buried, low visibility assets."
>
> Many elected officials

Common misconceptions include reducing IAM to a one-size-fits-all set of principles and solutions, mistaking it for a piece of software, substituting it for engineering technology, or believing that it can be altogether outsourced

In practical terms, many existing implementations tend to be biased by one or several of these perspectives.

What is not IAM?

- A piece of software
- A set engineering technologies
- An activity that can be totally outsourced
- A one-size-fits-all set of principles and solutions.

3.3 IAM multiple definitions

Infrastructure Asset Management (IAM) of urban water systems may be defined in many different ways.

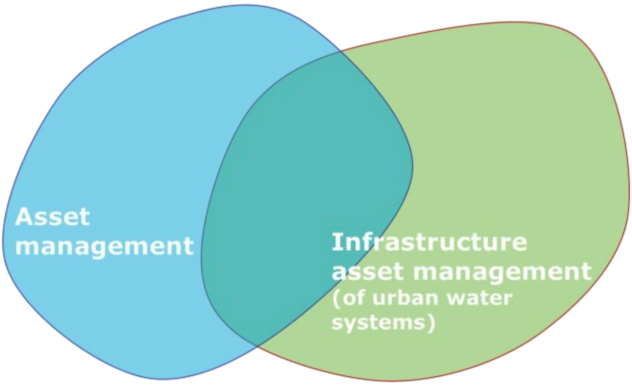
> "Asset management is the art of balancing cost, performance and risk in the long term."
>
> Brown & Humphrey (2005)

This definition brings the attention for the fact that asset management is not a pure science and that decisions cannot result from a fixed set of rules. Technical and cost considerations need to be combined with social, environmental and governance aspects.

> "Asset management is the set of coordinated activities that an organization uses to realize value from assets in the delivery of its outcomes or objectives. Realization of value requires the achievement of a balance of costs, risks and benefits, often over different timescales. Asset management can only be effective in the context of the organizational objectives and when considering the operating environment of the organization."
>
> ISO/DIS 55000: 2012

When dealing with the urban water services, the core assets are the physical infrastructures that compose the water systems, such as treatment and pumping facilities, pipes and sewers, storage tanks.

Given the system behaviour of these infrastructures and the fact that they aim at having indefinite lives (only the individual components have a useful life), infrastructure asset management is a subset of asset management in general, requiring some specific methods not applicable or relevant when managing other types of assets.

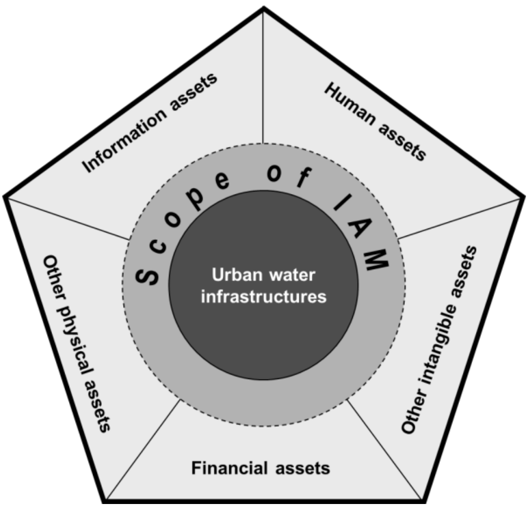


3.4 IAM TRUST approach

TRUST assumes the following definition for IAM:

Infrastructure asset management (IAM) of urban water services is the set of processes that policy makers and utilities need to have in place in order to ensure that infrastructure performance corresponds to service targets over time, that risks are adequately managed, and that the corresponding costs, in a lifetime cost perspective, are as low as possible, as a pillar of service sustainability.

IAM, although centered in the physical infrastructure, need to include the interfaces with the other main types of utility assets that impact the infrastructure or may be affected by it. The relationship between the urban water infrastructures and the other utility assets is shown as follows:



Information assets are particularly important for IAM because water infrastructures are mostly buried, and setting up diagnosis and prioritising interventions needs to be based on accurate inventories, reliable historical data of previous failures and interventions, and associated costs. It is equally important to have reliable information on the consumers' characteristics, needs, expectations and behaviour.

Human assets are critical for the success of IAM, which requires leadership, co-ordination and collaboration, corporate culture acceptance, team building, motivation, commitment and know-how.

Financial assets are fundamental to build, maintain and operate the systems. IAM strategies must be coordinated and consistent with financial strategies and planning.

Other support physical assets are needed, such as buildings, equipment and vehicles, to run the water systems.

Last but not least, **intangible assets**, such as image and credibility of the utility to the customers and to other stakeholders, are also crucial for IAM as they often drive the selection of the alternatives to implement.

3.5 Motivation and drivers

Urban water systems are the most valuable part of the public infrastructure worldwide, and utilities and municipalities are entrusted with the responsibility of managing and expanding them for current and future generations. Infrastructures inexorably age and degrade, while society places increasing demands for levels of service, risk management and sustainability.

As many systems reach high levels of deferred maintenance and rehabilitation (ASCE, 2009), the combined replacement value of such infrastructures is overwhelming, demanding judicious spending and efficient planning.

IAM methods partially differ from those applicable to managing other types of assets. One of the reasons is the fact that such infrastructures have indefinite lives, in order to satisfy the permanent needs of a specific public service. Infrastructures are not replaceable as a whole, only piecemeal. Consequently, in a mature infrastructure, all phases of assets lifetime coexist.

Additionally, in network-based infrastructures, it is frequently not feasible to allocate levels of service to individual components because there is a dominant system behavior (e.g. symptoms and their causes often occur at different locations).

IAM is increasingly becoming a key topic in the move towards compliance with performance requirements in water supply and wastewater systems. Sustainable management of these systems should respond to the need for:

- Promoting adequate levels of service and strengthening long-term service reliability;
- Improving the sustainable use of water and energy;
- Managing service risk, taking into account users' needs and risk acceptance;
- Extending service life of existing assets instead of building new, when feasible;
- Upholding and phasing in climate change adaptations;
- Improving investment and operational efficiency in the organization;
- Justifying investment priorities in a clear, straightforward and accountable manner.

3.6 Key international standards

As asset management is gaining relevance, new international standards are emerging. In particular:

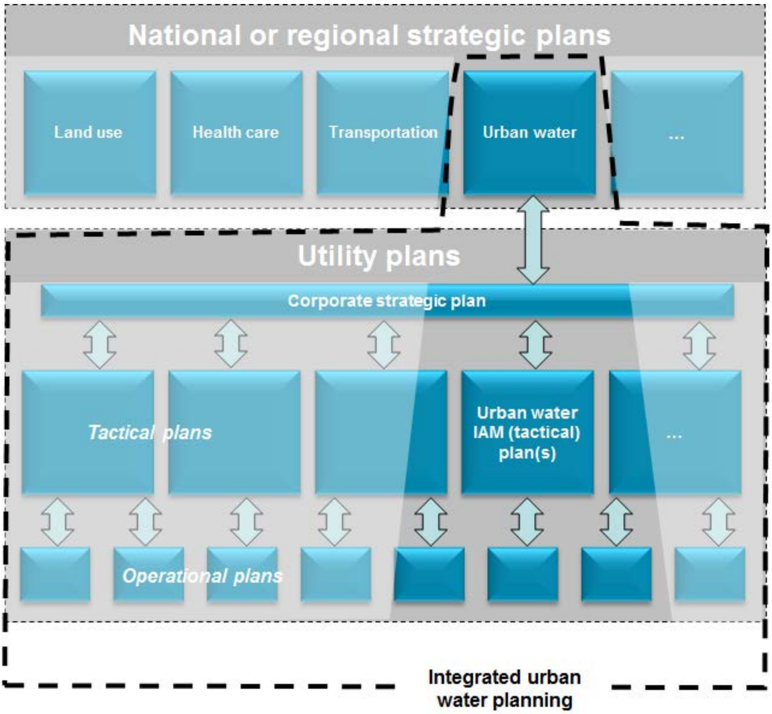
- the ISO 55000 series, which includes a standard on overview, principles and terminology (ISO 55000:2014),;
- a standard with requirements for management systems (ISO 55001:2014)
- and a standard on guidelines for the application of ISO 55001 (ISO 55002:2014).

As these documents are applicable to any type of assets, they may be faced as umbrella standards for infrastructure asset management.

Other relevant standards for IAM are the ISO 24510:2007, 24511: 2007 and 24512: 2007, on "Activities relating to drinking water and wastewater services", and the ISO 31000- 2008, on "Risk management".

3.7 IAM as a key process within the integrated planning of urban water services

Integrated planning of urban water services embraces both the national or regional planning level and the urban water utility level .



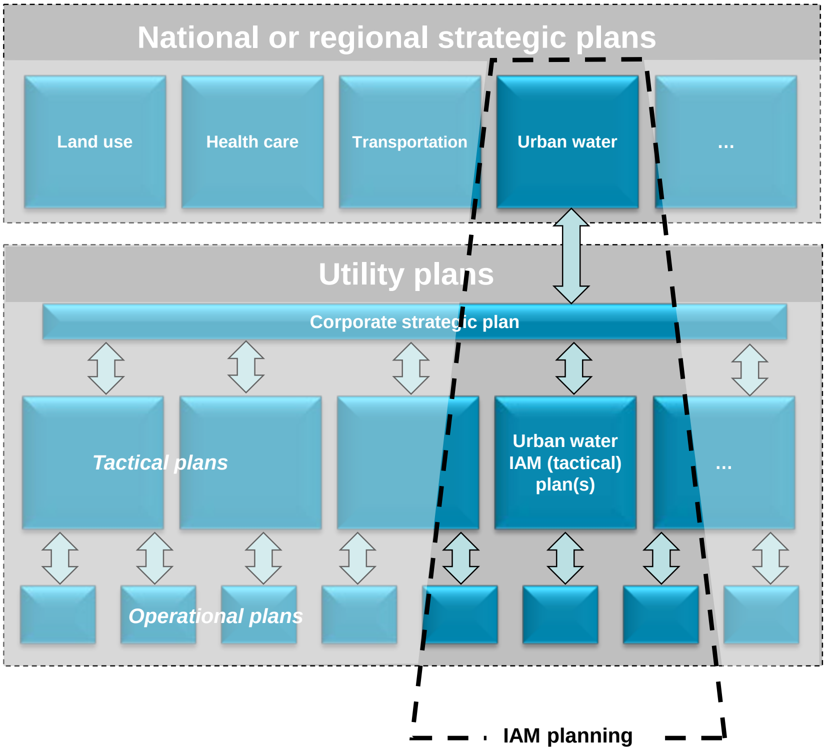
At a national or regional level, integrated planning should be coherent with public policies and articulated with the strategic planning for cities in general, and particularly with other public infrastructures (e.g. transportation of passengers, health care, education) and with the land use planning (e.g. master urban plans).

At the utility level, integrated planning needs to be aligned with the national or regional strategic plans, complying with the strategies established. It needs to be carried out at different levels of decision, consistent and aligned between them.

IAM planning is a key element of the utility global planning:

- at a corporate long term level, infrastructure asset management is dealt with in a macro way, as part of the global service objectives and strategies;
- at a tactical medium term level, multiple thematic plans may coexist (e.g., human resources, customer service, or financial plan) with the infrastructure asset management plan;
- at an operational level, the established IAM tactics are converted into short-term action plans.

Integrated planning requires monitoring at each level and feedback mechanisms between every two successive levels.



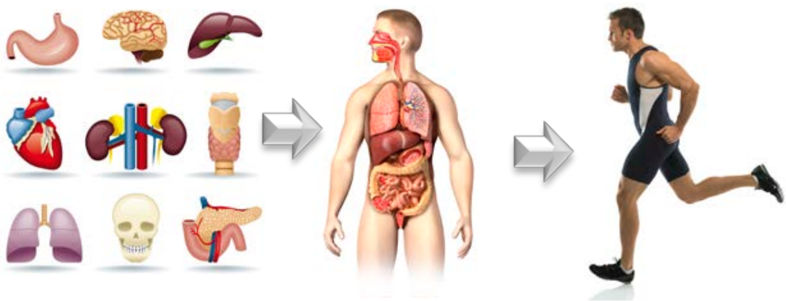
Understanding urban water systems' metabolism

4

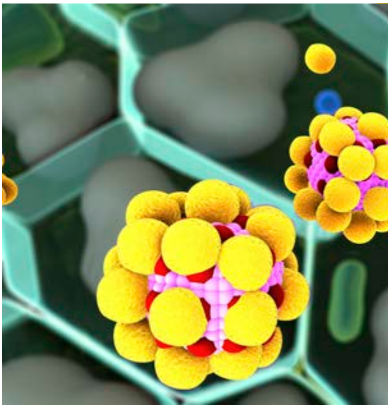
4.1 Urban water systems behave as organic bodies

Urban water systems evolve over time similarly to an organic body, the performance depends on the functionality of vital organs.

In living bodies, backbone and muscles provide the structure, but blood circulation, a functioning liver and brain, are key for a healthy body. They need to consume nutrients, water and oxygen in order to live and function. They generate by-products, some of them are reused.



Urban water systems have complex behaviours that can be addressed, from the physical perspective, as they were a living metabolism: the backbone is the infrastructure, the vital organs are the management processes.



Metabolism (from Greek *metabolismós*) is the set of chemical reactions that happen in living organisms to maintain life.

These processes allow organisms to grow and reproduce, to maintain their structures, and to respond to their environments. The notion of metabolism has also been applied outside the discipline of biology, such as, urban metabolism and industrial metabolism.

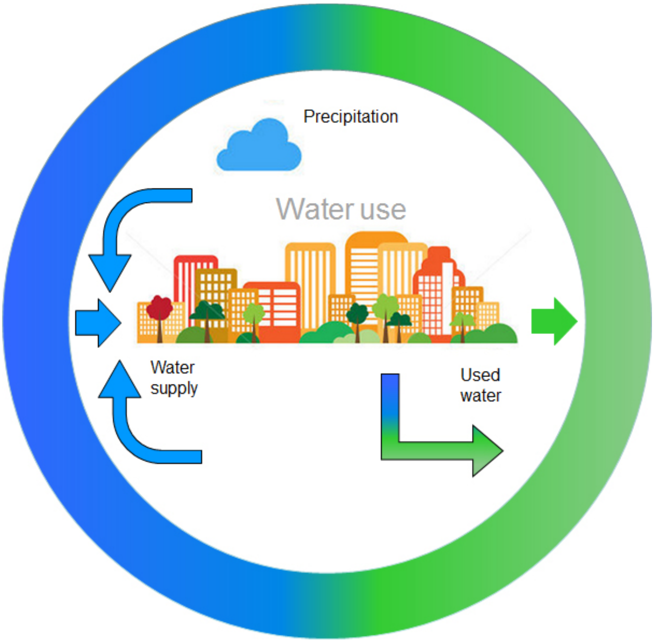
They consume resources (e.g., water, chemicals and other materials, manpower, energy, capital), provide functions (in this case services) with given levels of performance and associated risks, and generate outflows, such as waste, by-products and emissions to water and air.

The physical components and the technologies of the urban water infrastructure operate under given local boundary conditions (geographic, climatic and socio-economic).

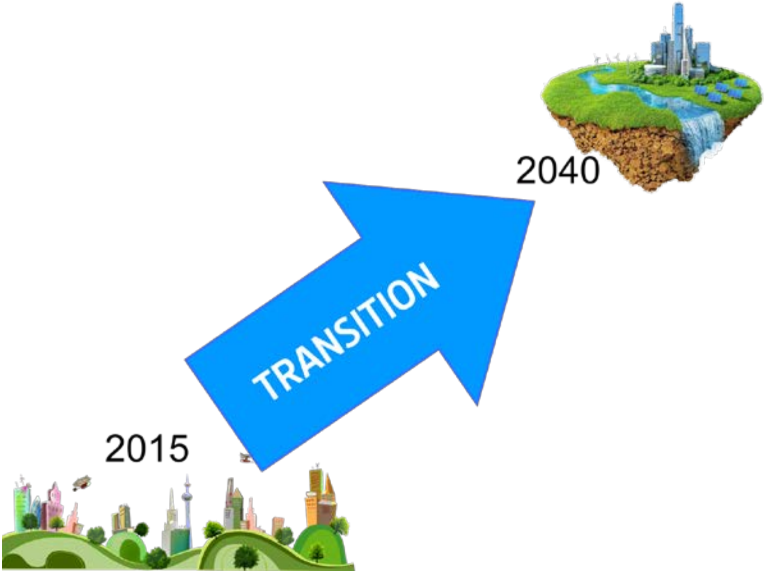
4.2 Why financial efficiency requires the understanding of the infrastructure metabolism?

The choice, the design and the operation of technologies critically influence the overall quality of the urban water services in terms of performance, risk and cost, as well as the overall system sustainability.

The metabolism depends not only on the specific characteristics of the systems, but also on the local boundary conditions, including technology and management decisions.



Understanding the metabolism of the urban water systems helps managing the transition paths and choosing the best options to pave the way towards more sustainable services.



The application of metabolism models to industrial processes and to cities behavior is a still relatively a new field of research (Barles, 2010), although it has already been used for some time.

For instance, Browne *et al.* (2009) has measured metabolism inefficiencies for different sectors (e.g. food, textiles, paper) by relating the final disposal of wastes to consumption in the city of Limerick in Ireland.

However, metabolism models had never been developed or applied to the urban water cycle services prior to TRUST.

4.3 The TRUST metabolism model

The TRUST metabolism model can be used to provide a physical basis for quantifying resource flows and for quality and sustainability assessment of future intervention strategies in urban water services in the long term.

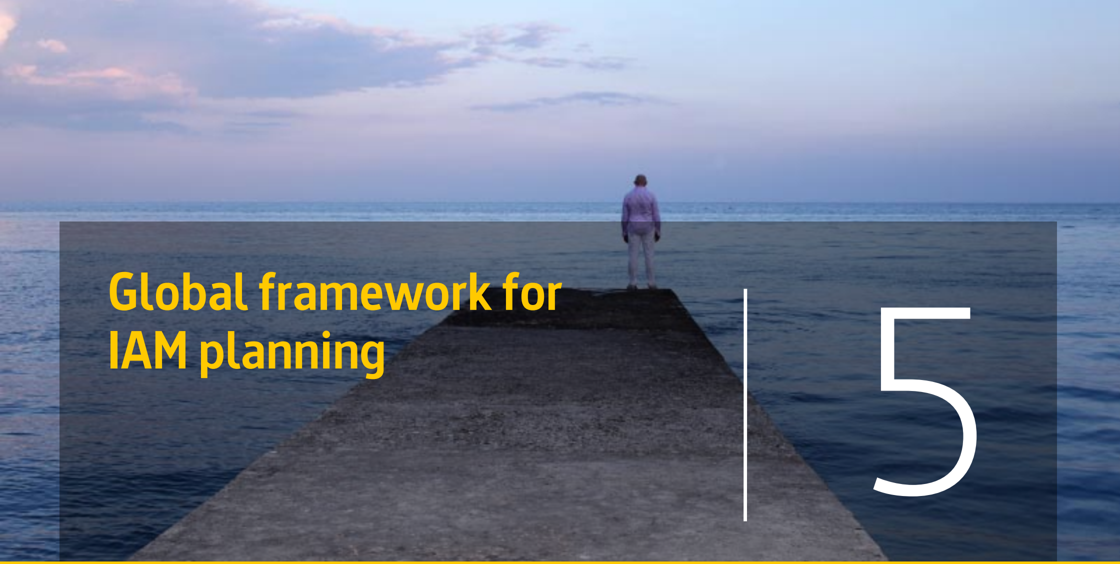
When referring to the metabolism of an urban water system, there is a need to consider relevant flows and conversion processes of all kinds of materials and energy, which are mobilized by the development and operation of the system in order to fulfill the necessary functions.

As a result of including the cyclic water recovery and resource recovery subsystems, the metabolism modelling may in a direct way also address emerging opportunities such as decentralised stormwater/wastewater management and recovery, use of treated wastewater, and recovery of resources from all parts of the system (i.e. any kind of material and energy recovery option).

The objective of a metabolism model is to directly assist water utilities in their systematic search for strategic improvements.

Metabolism studies tend to be data-demanding and to have a non-straightforward application. The TRUST metabolism model was developed with a complexity that limits its applicability to cities with reliable and comprehensible data systems. However, if the model as such is not applicable, it is important, at least, to identify and quantify the key resources needed (water, materials, manpower, energy), the outflows produced (waste, by-products and emissions) and the main mass-balances for each transition path or technological solution considered.

In this way, the metabolism approach supports the utility in the better understanding of critical system variables and the selection of the best infrastructure asset management options.



Global framework for IAM planning

5

5.1 The IAM cube

Regardless of the complexity of urban water systems and of the management organisations, there is always a need to address IAM from strategic, tactical and operational perspectives.

The ultimate aim is to ensure a balance between performance, cost and risk in the long term.

IAM requires a multidisciplinary approach, the main competences of which are business management, engineering and information management.

The cube symbolizes this recommended IAM approach.

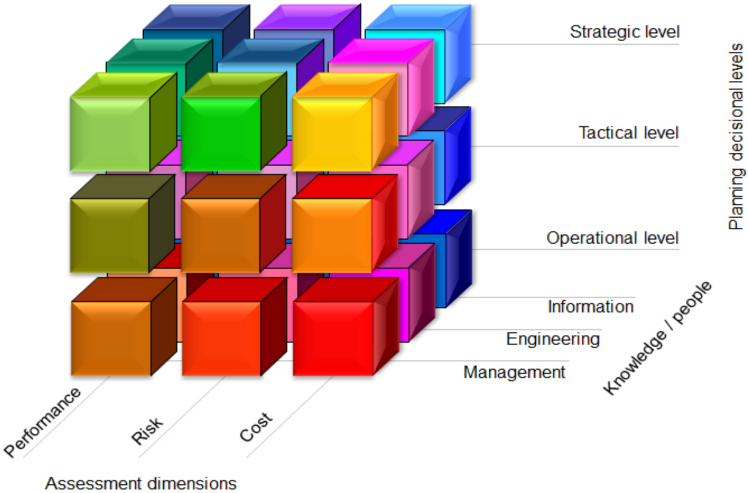


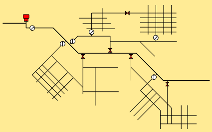
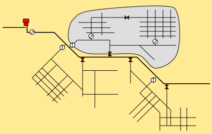
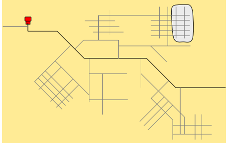
Figure 15 – The global IAM approach (Alegre & Covas, 2010)

5.2 Planning decisional levels

It is essential, that IAM is addressed at different planning decisional levels (INGENIUM, IPWEA, 2011; Alegre & Covas, 2010; Almeida & Cardoso; Alegre et al., 2012):

- *strategic level*, driven by corporate and long term views and aimed at establishing and communicating strategic priorities to staff and citizens; stakeholder analyses recommended
- *tactical level*, where the intermediate managers in charge of the infrastructures need to select the best medium-term intervention solutions;
- *operational level,* where the short-term actions are implemented.

The main characteristics and differences between the planning levels in terms of scale, scope, type of action and planning horizons are summarized as follows:

LEVELS	STRATEGIC	TACTICAL	OPERATIONAL
Scale	Macro-scale 	Intermediate scale 	Detail 
Scope	Global system 	Subsystems and critical assets 	Clusters of assets 
Type of action	Establishes the direction 	Defines the path 	Executes 
Planning horizon	Long term (10 to 20 years) 	Medium term (3 to 5 years) 	Short term (1 or 2 years) 

5.3 Planning horizons and analysis horizons

Given the long useful life of many assets of the urban water infrastructures, it is highly recommended that long term objectives and analysis horizons are adopted. Analysis horizons may be of the order of 30 to 100 years. There is always a balance.

Planning horizons, corresponding to the intervention period being incorporated in a given plan, may be shorter than the analysis horizon.

However, there is a clear need for long term strategic plans of the urban water services, both at the national or regional level and at the utility level. Planning horizons of 15-20 years are frequently adopted.

Typical planning horizons for tactical plans are 3 to 5 years and for operational plans 1 year.

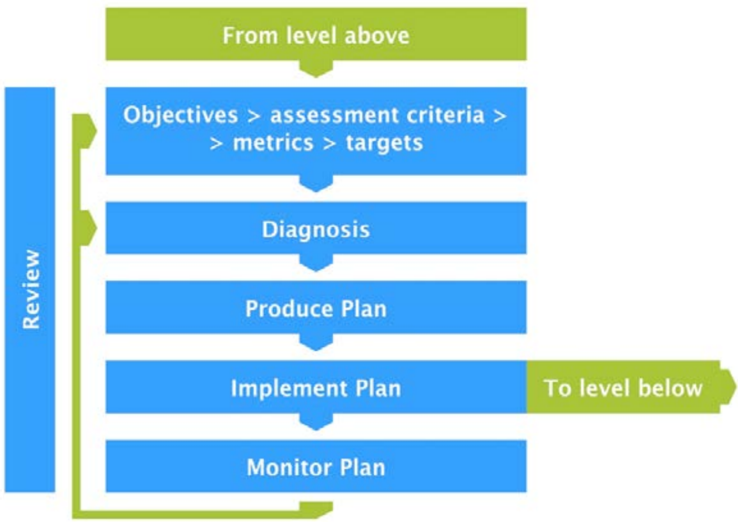
Planning horizons may significantly differ from case to case.

5.4 Planning process

At each level of management and planning – strategic, tactical and operational – a structured loop comprises the following stages:

- definition of objectives and targets;
- diagnosis;
- plan production, including the identification, comparison and selection of alternative solutions;
- plan implementation;
- monitoring and review.

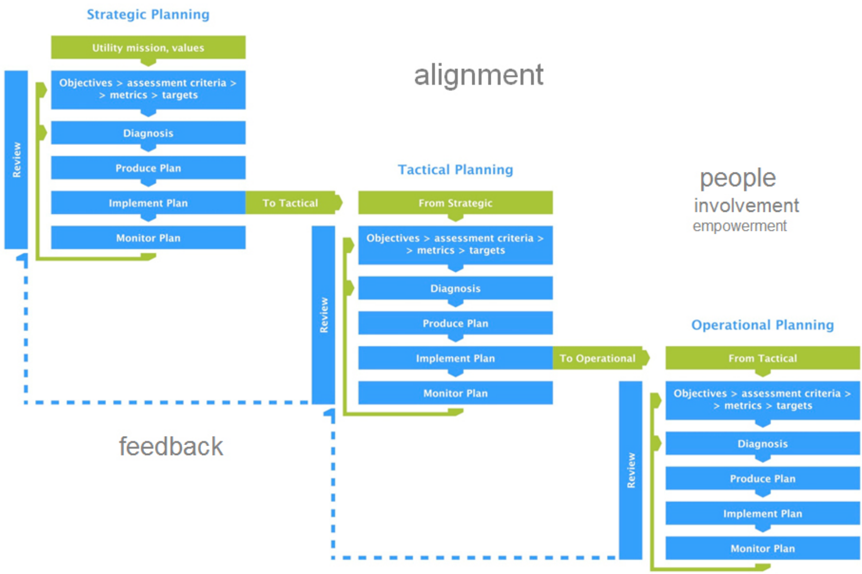
Most utilities already have several elements of this process in place. What is often missing is an effective alignment between the different management levels and a review mechanism, which is a way to measure compliance with set goals.



Establishing objectives, assessment criteria, metrics and targets is a crucial stage in order to set up clear directions of action, as well as accountability of results through timely review, within a given time frame (short, medium or long-term) (ISO 24510:2007, 24511:2007, 24512:2007).

These metrics and targets are an essential basis for establishing the diagnosis, prioritizing intervention solutions and monitoring the results.

The process cascades through the decisional levels within the management structure.



The global approach is based on plan-do-check-act (PDCA) principles aiming at the continuous improvement of the IAM process. The key notions in this process are:

- alignment among the decisional levels and their actors;
- bottom-up feedback;
- and involvement and empowerment of the entire organization, from the CEO to the asset operators, in order to promote leadership, co-ordination, collaboration, corporate culture acceptance, motivation, commitment and corporate know-how.

IAM aims at ensuring that, in a long-term perspective, service performance is kept adequate, risks incurred are acceptable and the corresponding costs are as low as feasible. Assessing performance, risk and cost is therefore key to effective IAM.

5.5 Performance assessment

Performance may translate either the efficiency or the effectiveness of the service. Performance assessment is a widespread activity used in economics, business, sports and many other walks of life in general, in order to compare and score entities and individuals and take management or other decisions (Alegre et al., 2000, Matos et al., 2003, Alegre et al. 2006, Cabrera & Pardo, 2008, Sjovold et al. eds., 2008, ISO 24510, ISO 24511, ISO 24512).

> **Assessment** is defined as a
>
> "process, or result of this process, that compares a specified subject matter to relevant references"
>
> ISO 24510

Performance assessment is therefore any approach that allows for the evaluation of the efficiency or the effectiveness of a process or activity through performance measures. Performance measures are the specific parameters that are used to inform the assessment.

The principal categories of performance measures include (Sjovold et al., 2008):

Performance indicators

Performance indicators are quantitative efficiency or effectiveness measures for the activity of a utility. A performance indicator consists of a value (resulting from the evaluation of the "processing rule") expressed in specific units, and a confidence grade which indicates the quality of the data represented by the indicator. Performance Indicators are typically expressed as ratios between variables; these may be commensurate (e.g. %) or non-commensurate (e.g. $/m^3).

The information provided by a performance indicator is the result of a comparison (to a target value, previous values of the same indicator, or values of the same indicator from other undertakings) (Alegre et al. 2006; ISO 24500, Sjovold et al., 2008).

Performance indices

Performance indices are standardized and commensurable measures, that may result from the combination of more disaggregated performance measures (e.g. weighted average of performance indicators) or from analysis tools (e.g. simulation models, statistical tools, cost efficiency methods).

Sometimes they aim at aggregating several perspectives into in a single measure (Alegre, 2008, Sjovold et al., 2008). Differently from the performance indicators, they contain a judgment in itself, intrinsic to the standardization process (e.g. 0 – no function; 1 – minimum acceptable; 2 – good; 3 – excellent).

Performance levels

Performance levels are performance measures of a qualitative nature, expressed in discrete categories (e.g. excellent, good, fair, poor).

In general they are adopted when the use of quantitative measures is not appropriate (e.g. evaluation of customer satisfaction by means of surveys) (Alegre, 2008, Sjovold et al., 2008).

Performance indicators may be converted into performance indices through the application of a performance function, or into performance levels when they are compared with reference levels, in order to support interpretation or multi-criteria analyses. Such transformations may be particularly useful in the graphical representation of a set of performance indicators.

5.6 Risk assessment

Risk analysis may address an organization in its entirety, a system or sub-systems (aggregated or lumped analysis), or individual system components (component or discrete analysis). Risk assessment may be carried out in many different ways, and is often (though not always) quantifiable.

For instance, if the probability of failure of every pipe in a network is known, as well as its consequence, expressed in terms of the ensuing reduced service (unmet demand), the total risk of not supplying the users may be expressed as the expected value of the annual unmet demand (Vitorino *et al.*, 2012).

Risk analysis is a vast field of expertise where several mainstream frameworks have been developed for infrastructure-based problems, such as fault-tree analysis or the approaches centered on risk matrices (Almeida *et al.*, 2010). The latter is one of the most versatile and structured formalisms available when approaching the range of (quantifiable or unquantifiable) risks that are faced by urban utilities, and is based on a thorough analysis of risk consequences and on the categorization into both probability and consequence classes.

Probability classes can be defined by different probability intervals that may be derived, typically, from linear, exponential or logarithmic functions. The selection of probability classes is done by the decision maker; the criteria are not only depending on the type of problem but also on the range of possibilities acceptable to the decision maker, thus related to her perception of risk.

Probability and probability classes are assigned to each individual component of the system when dealing with a component-based analysis or to an area/sector when the analysis is focused on an area with specific and known risk features.

Independently of the type of failures that may take place, they can result in a range of potential consequences not only to the water infrastructure and services but also to other infrastructures. Moreover, consequences can also include socio-economic disruptions and environmental impacts.

Therefore, when assessing the risk associated with a specific event, several **consequence dimensions** should be taken into consideration (Almeida et al., 2011) :

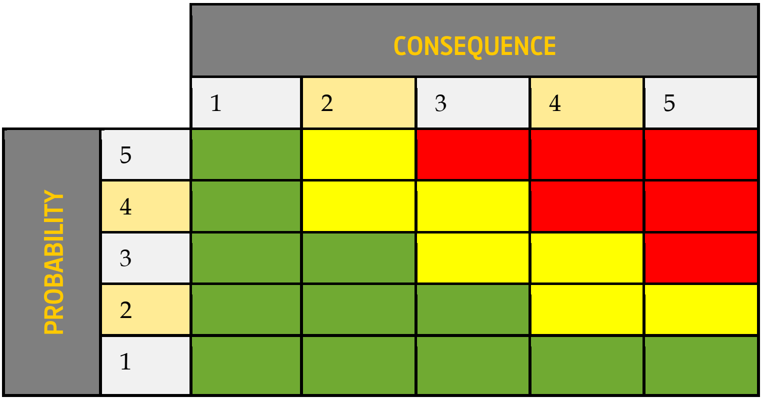
DIMENSION	TYPE OF VARIABLES TO EXPRESS RELATIVE VALUE IN EACH CLASS
Health and safety	– number and severity of injuries – number and severity of people affected by disease – number of people affected permanently (mortality and disability)
Financial	– monetary value; should be a function of the size of utility e.g. annual operating budget (AOB)
Service continuity	– duration of service interruption (availability and compliance with minimum standards); differentiation of type of client affected can be used (residential, hospital, firefighting)
Environmental impacts	– severity e.g. expressed as expected time for recovery (long-term "> y years"; mid-term "x to y years"; short-term "w to v months"; rapid recovery "less than w months") – extent (e.g. dimension of area, water quality index, volume or duration of event) – vulnerability (e.g. protected areas, abstraction areas of influence for water supply)
Functional impact on the system	– various performance measures (e.g. population/clients not supplied for a T > D interruption; client.hours without supply); thresholds can be associated with legal requirements
Reputation and image	– number of complaints; number of times the name of the utility appears in the media, ...
Business continuity	– damage to materials, service capacity, available human resources to maintain system function and recovery time (e.g. % capacity affected.hours)
Project development	– effect on deviation of objectives (e.g. scope, schedule, budget)

Although other **classes of consequences** may be adopted, a typical classification might look like this:

- 1 – insignificant;
- 2 – low;
- 3 – moderate;
- 4 – high;
- 5 – severe.

The way in which probability and consequence are combined reflects the degree of cautiousness of the analyst, which may vary.

See an exemple of a moderate risk perception matrix:



A risk matrix should have at least three risk levels (low, medium and high risks) that are to be associated with the **acceptance levels of risk** (Almeida *et al.*, 2010):

- Low or acceptable risk (green);
- Medium or tolerable risk (yellow);
- High or unacceptable risk (red).

5.7 Cost assessment

Cost assessment is the other fundamental axis of analysis for comparing and selecting intervention alternatives in an IAM framework. All relevant costs and revenues items that take place during the analysis horizon and which differ from the *status quo*, should be accounted for, for any of the intervention alternatives considered.

The inclusion in the analysis of cost items that are common in nature and value to all alternatives is optional, as they will not have an effect on the comparison but may be useful in informing it. However, if quantifying **the actual net present value**[1] or **internal rate of return**[2] of a financial project is important to the exercise, then all the relevant costs and revenues must be included.

In practice, it is often the case that rehabilitation interventions do not affect revenues, and mainly have an effect on system performance, on system risk (by affecting system reliability) and on capital and operational costs (e.g., repair costs, complaint management, regulatory or contractual service compliance failure).

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[1] **Net present value:** The sum of the discounted future cash flows. If only costs are included, this can be referred as net present cost (ISO 15686-5: 2008)

[2] **Internal rate of return**: the "rate of return" that makes the net present value of all cash flows (both positive and negative) from a particular investment equal to zero. In other words, the discount rate at which the present value of all future cash flow is equal to the initial investment.

In general and simplified terms, the main cost items include:

- **Investment costs**, expressed as a given amount at a given point in time, and with a given depreciation period (if not linear, a depreciation function must be known as well).
- **Operational costs**, normally organized in three classes: (i) cost of goods sold; (ii) supplies & external services; (iii) personnel; operational costs are expressed as annual values, over the analysis period.
- **Revenues**, either through lump sums occurring at specific points in time (e.g. public subsidies), or distributed over the analysis period (e.g. revenues from tariffs). Revenues are also expressed by their annual value over the analysis period.

Whenever relevant, the costs of planning and designing new assets, as well as disposal costs of assets that reach the end of their service lives, should be included.

Since the end of the analysis horizon does not coincide in general with the end of the service life of most assets, the residual value of all assets at the end of the analysis period must be considered.

Cost-benefit analysis may include not only tangible costs and revenues for the utility, as described above, but also tangible for a third parties (e.g., consumers, society) and intangible costs and benefits. However, practice shows that utilities often do not feel comfortable in expressing certain of such costs and benefits in monetary terms (e.g., increasing public health risk because the water quality does not meet the targets).

A recommended option, successfully implemented in a good number of utilities (Leitão *et al.*, 2013), is to express tangible costs for a third parties and intangible costs and benefits as performance or risk metrics, and to include only tangible costs and revenues for the utility in the cost axis of the analysis.

> "Tangible costs for a third parties and intangible costs and benefits can be described as as performance or risk metrics."
>
> Leitão et al. (2013)

UWCS performance assessment system

6

6.1 Introduction

The final goal of any performance assessment system (PAS) is to provide information. It is important to make the distinction between information and data. A correct definition for information would be “data that can be used for the purpose of making decisions”. Consequently, a system of performance indicators is not only aimed at providing the value of a few ratios, but also all the complementary elements (quality of the data, explanatory factors, context) which are needed in order to make appropriate decisions.

The performance assessment system is consequently the result of considering all areas of interest, stakeholders and influencing factors in a certain environment. In the case of water undertakings, the considered system would comprise the whole company, the stakeholders, the users, the environment, and all related areas that may be worth monitoring for management purposes.

Setting up objectives, assessment criteria, metrics and targets is a crucial stage in order to set up clear directions of action, as well as accountability of results through timely review. This sequence shall be followed to establish TRUST PAS. Clarifying the four distinct but sequential concepts:

- Objectives are the goals that the organization aims to achieve. According with the ISO 24510:2007, 24511:2007, 24512:2007 standards, TRUST performance assessment should always be linked to objectives that are clear and concise, as well as ambitious, feasible and compatible, and take into account the ultimate goal for the utility of providing a sustainable service to society. For each objective, it is recommended that key assessment criteria be specified.

- Assessment criteria are points of view that allow for the assessment of the objectives. For each criterion, performance, risk and cost metrics must be selected in order for clear targets to be set, and for further monitoring of the results.

- Metrics are the specific parameters or functions used to quantitatively or qualitatively assess criteria; metrics can be indicators, indices or levels.

- Targets are the actual proposed values to be achieved for each metric within a given time frame (short, medium or long term).

As a consequence, a performance assessment system comprises a set of performance assessment metrics and related data elements which represent real instances of the undertaking context. The classification of these data elements depends on the active role they play:

- Data elements: A basic datum from the system which can either be measured from the field or is easily obtainable. Depending on their nature and role within the system, data elements can be considered variables, context information or simply explanatory factors.

- Variables: A variable is a data element from the system which can be combined into processing rules in order to define the performance assessment metric. The complete variable consists of a value (resulting from a measurement or a record) expressed in a specific unit, and its reliability level (see section, 0, Table 1) which indicates the quality of the data represented by the variable.

- Performance assessment metrics: Measures of the efficiency or effectiveness of the delivery of the urban water services. Section 0 specifies the types of performance metrics that can be used and their characteristics. They should always be associated to objectives and assessment criteria.

- Context information: Context information are data elements that provide information on the inherent characteristics of an undertaking and account for differences between systems. There are two possible types of context information:
  - **Information** describing pure context and external factors to the management of the system. These data elements remain relatively constant through time (demographics, geography, etc.) and in any case are not affected by management decisions.
  - **Some data elements** on the other hand are not modifiable by management decisions in the short or medium term, but the management policies can influence them in the long term (for instance the state of the infrastructure of the utility).

Context information is especially useful when comparing indicators from different systems.

- **Explanatory factors**: An explanatory factor is any element of the system of performance indicators that can be used to explain PI values, i.e., the level of performance at the analysis stage. This includes PI, variables, context information and other data elements not playing an active role before the analysis stage.

The use of performance indicators should always be linked to the establishment of a proper system of performance indicators, in which all the above mentioned elements are present and defined, and aim to fulfil a clear objective or obtain information on specific areas or issues.

The proposal in this manual represents in itself a complete system of performance indicators that can be used on an "as is" basis, completed with further elements or simplified through a selection of part of its elements to suit particular needs.

6.2 Types of performance assessment metrics used in TRUST

Assessment is defined as a "process, or result of this process, comparing a specified subject matter to relevant references" (ISO 24510: 2007; ISO 24511: 2007; ISO 24512: 2007).

Performance assessment is therefore any approach that allows evaluation of the efficiency or the effectiveness of a process or activity through the production of performance metrics. Performance metrics are the specific measures that are used to inform the assessment.

The types of performance assessment metrics that are recommended to be used within TRUST are:

- Performance indicators
- Performance indices
- Performance levels

For the definition of these metrics see section 5.5.

6.3 Requirements for the definition of a performance assessment system

A good number of problems which originate in the use of performance indicators can be solved in advance at the definition stage of the PI system. Setting the objectives and constraints of the system is helpful when choosing and defining the indicators.

Although the definition and selection of performance indicators is dealt with in the implementation chapter, there are a few principles for the elements of a PI system that should be taken into account at the definition stage.

6.4 Performance assessment metrics

Individually, a performance assessment metric (PAM) should comply with the following requirements:

- be relevant for the objectives of the UWCS;
- fit in the predefined assessment criteria:
- be clearly defined, with a concise meaning;

- be reasonably achievable (which mainly depends on the related variables);
- be auditable;
- be as universal as possible and provide a measure which is independent from the particular conditions of the utility;
- be simple and easy to understand; and
- be quantifiable so as to provide an objective measurement of the service, avoiding any personal or subjective appraisal.

Collectively, PAMs should comply with the following requirements:

- each PAM should provide information significantly different from the other PAMs;
- definitions of the PAMs should be unequivocal (this requirement is made extensive to its variables);
- only PAMs which are deemed essential for effective performance evaluation should be established.

6.6 Variables

Each variable should comply with the following requirements:

- definitions should be univocal;
- fit the definition of the PI they are used for;
- be reasonably achievable;
- refer to the same geographical area and the same period of time or reference date as the PI they will be used for;

- be as reliable and accurate as the decisions made based on them require.

Some of the variables in PAS are often obtained from external data, and their availability, accuracy, reference dates and limits of the corresponding geographical area are generally out of the control of the undertaking. In this case, variables should also comply with the following requirements:

- be collected, whenever possible, from official survey departments;
- be fundamental for the PAM assessment or interpretation; and
- collectively, be as few as possible.

6.7 Context information and other data elements

Context information (CI) and the rest of the data elements in the system (which are used as explanatory factors) should follow the same general principles as variables and performance indicators. However, the level of detail and confidence grading is usually not considered to be as high as the one required for PI and variables. Consequently, CI and the rest of the data elements should comply with:

- definitions should be univocal;
- be reasonably achievable;
- if external, be collected whenever possible from official survey departments;
- be fundamental for the PI interpretation; and
- collectively, be as few as possible.

6.8 Data quality

Performance metrics should always be associated with the quality of the data used to calculate them. Ideally, this should be assessed in terms of the reliability of the source and of the accuracy of data. However, practice has shown that in most practical situations it may not be easy to assess the accuracy of the data.

The reliability of the source accounts for uncertainties in how reliable the source of the data may be, i.e., the extent to which the data source yields consistent, stable, and uniform results over repeated observations or measurements under the same conditions each time.

Within TRUST, it is recommended that reliability of the input variables is well defined, according to the IWA PI guidelines, reproduced as follows:

RELIABILITY	DEFINITION
★★★	Highly reliable data source: data based on sound records, procedures, investigations or analyses that are properly documented and recognised as the best available assessment methods.
★★	Fairly reliable data source: worse than ★★★, but better than ★.
★	Unreliable data source: data based on extrapolation from limited reliable samples or on informed guesses.

7 Technological challenges and opportunities

The transition for more sustainable urban water systems is greatly dependent on the right selection and implementation of appropriate technological solutions.

The main technological challenges and opportunities are in the following domains:

- Safe and sustainable water supply
- Urban water demand management
- Wastewater and stormwater systems's management in UWSC
- Alternative water sources
- Strengthening the water-energy nexus in urban water systems (water-energy connection)
- Enhanced technologies for infrastructure asset management

It should be highlighed that the domain Urban water demand management covers the aspects under the control of the utilities (e.g. water losses management, resulting into lower water resources needs) as well as alternative water sources and water savings at the end-user level, which result into lower water demand. The domain Alternative water sources covers only the water sources that supply the public system.

The domains and main challenges in each domain are presented as follows.

DOMAIN	MAIN CHALLENGES
Safe and sustainable water supply	Inadequacy of current systems to cope with emerging challenges associated with water stress (quantity and quality) and climate change (temperature increase, sea level water increase, extreme events occurrence)
Urban water demand management	Increasing constraints in water availability, increasing production costs of drinking water (due to water quality deterioration in the sources and to more demanding legislation) , increasing environmental protection pressures (water abstraction, CO2 emissions, water pollution), and need to improve the economic efficiency of the utilities
Wastewater and stormwater systems's management (collection, drainage, treatment discharge) in UWSC	Increasing treatment costs of wastewater (due to more demanding legislation) , increasing environmental protection pressures (CO2 emissions and water pollution), and need to improve the economic efficiency of the utilities
Alternative Water Sources	Increasing constraints in water availability
Strengthening the water-energy nexus in urban water systems (water-energy connection)	Increasing environmental protection pressures (CO_2 emissions) and economic pressures (cost reduction)
Enhanced technologies for infrastructure asset management	Unknown condition of buried assets, aging infrastructures and decreasing levels of service.

The technologic opportunities and the methods and technologies developed within TRUST have been identified and are highlighed in the following tables.

DOMAIN	TECHNOLOGICAL OPPORTUNITIES	METHODS/TECHNOLOGIES COVERED IN TRUST
Safe and sustainable water supply	Source protection and control	Not covered
	Enhanced water treatment	trust >> Table 1
	Water quality monitoring and control	Not covered
	Risk management and urban water safety planning	Not covered
Urban water demand management	Integrated planning of water demand, energy consumption and wastewater production	trust >> Table 2
	Water losses management	trust
	Metering and tariff structures	trust
	Use of household fittings and appliances	trust
	Soft UWDM technologies	trust
	UWDM technologies for non-domestic sectors (industry and public services)	Not covered
	User greywater/rainwater harvesting systems	trust

DOMAIN	TECHNOLOGICAL OPPORTUNITIES	METHODS/TECHNOLOGIES COVERED IN TRUST
Wastewater and stormwater systems's management in UWSC	o Integrated planning of wastewater and storm water o Performance assessment o Infiltration and inflow control o Enhanced wastewater treatment	trust >> Table 3 trust trust trust
Alternative Water Sources	o Use treated wastewater o City rainwater harvesting systems o Desalination	trust >> Table 4 Not covered trust
Strengthening the water-energy nexus in urban water systems (water-energy connection)	o Integrated planning of water and energy o Enhanced energy efficiency technologies/equipment o Energy recovery technologies	trust >> Table 5 trust trust
Enhanced technologies for infrastructure asset management	o Integrated IAM planning o Enhanced technologies to support data collection and information management o Enhanced rehabilitation technologies	trust >> Table 6 trust trust

Table 1 >> Domain: Safe and sustainable water supply

TYPES OF METHODS AND TECHNOLOGIES	METHODS AND TECHNOLOGIES FOR IMPROVEMENT COVERED IN TRUST	TECHNOLOGY OR TOOL
Enhanced water treatment	NOM fractionation/Rapid NOM fractionation	Techn.
	BDOC analyses	Techn.
	Full-scale coagulation treatment optimization procedures/Roadmap	Techn.
	BDOC analyses	Techn.
	Water treatment optimization – incl mapping of optimization benefits - with respect to: i) safety/water quality, ii) sustainability /use of resources use,) and iii) distribution/biostability	Tool
	LCA - as a tool for assessing environmental impacts of coagulant type selection, coagulant processing/manufacturing, transport distance, resources use/coagulant doses, energy use, sludge handling, etc.	Tool
	Optimization as a tool for balancing safety/treated water quality and sustainability/resources use	Tool

Table 2 >> Domain: Alternative Water Sources

TYPES OF METHODS AND TECHNOLOGIES	METHODS AND TECHNOLOGIES FOR IMPROVEMENT COVERED IN TRUST	TECHNOLOGY OR TOOL
Integrated planning of water demand, energy consumption and wastewater production	Development and implementation of a plan (aiming at the reduction of water demand, energy consumption and wastewater production)	Methodology
	Impact assessment tool for assessing the impacts of different combinations of WDM interventions above on with respect to their cost, water-related energy use and impact on supplydemand balance of water distribution systems.	Tool
Water losses management	Water losses management	Methodology
	PaVLOS stand alone software (leakage reduction, energy optimisation)	Tool
Metering and tariff structures	Metering and tariff structures	Methodology
Use of household fitttings and appliances	Efficient household micro-component appliances and fittings – WCs, baths, showers, washbasin taps, kitchen sink taps, dishwashers, washing machines, outdoor taps	Technology
Soft UWDM technologies	Soft technologies (e.g. education; media campaigns)	Technology
User greywater and rainwater harvesting systems	Alternative water systems – grey water recycling systems (GWR), rainwater harvesting (RWH) systems, sustainable urban drainage systems (SuDS)	Technology

Table 3 >> Domain: Wastewater and stormwater systems's management in UWSC

TYPES OF METHODS AND TECHNOLOGIES	METHODS AND TECHNOLOGIES FOR IMPROVEMENT COVERED IN TRUST	TECHNOLOGY OR TOOL
Integrated planning of wastewater and storm water	STORM model: Creation of disconnection potential maps for SUDS (sustainable urban drainage systems) introduction	Tool
	INFOWORK model for prediction CSO (combined sewer overflow) frequency and intensity.	Tool
Performance assessment	PASTool has a set of indicator espacially developed to determine the performance of water and wastewater treatment plants	Tool
Enhanced wastewater treatment	Aeration in WWTP: energy efficient bubble aerators, on line aeration control	Technology
	Nutrient removal: ensuring correct sludge age, ammonia derived DO control, separate treatment of reject sludge water for N-removal	Technology
	Mixers: high yield equipment, combined mixing with pumping and/or aeration	Technology
	UV treatment: enhanced inflow quality, dosing rate variation with effluent quality	Technology
	Sludge thickening: low energy equipment (e.g. belts)	Technology
	Sludge end treatment: maximum dewatering to reduce drying energy demand	Technology

Table 4 >> Domain: Wastewater and stormwater systems's management in UWSC

TYPES OF METHODS AND TECHNOLOGIES	METHODS AND TECHNOLOGIES FOR IMPROVEMENT COVERED IN TRUST	TECHNOLOGY OR TOOL
Use treated wastewater	Use of treated wastewater	Technology
	Modelling different reuse roadmaps	Technology
	Ceramic membranes to reclaim water for urban multi-purposes	Technology
Desalination	Sea water desalination	Technology
	Brackish water desalination	Technology
	Plant Audit as tool to assess performance (desalination: energy optimisation and brine handling)	Tool

Table 5 >> Domain: Strengthening the water-energy nexus in urban water systems (water-energy connection)

TYPES OF METHODS AND TECHNOLOGIES	METHODS AND TECHNOLOGIES FOR IMPROVEMENT COVERED IN TRUST	TECHNOLOGY OR TOOL
Integrated planning of water and energy	Integrated pressure and energy management in water distribution	Methodology
	Energy efficiency audits	Methodology
Enhanced energy efficiency technologies/ equipment	Wastewater treatment with P-recovery (as struphite)	Technology
	Wastewater treatment with AB-system (Dynafil)	Technology
	Enhanced sludge digestion	Technology
Energy recovery technologies	Heat recovery from wastewater effluent	Technology
	Heat and cold recovery from (waste)water (sewer system), in particular combined with aquifer thermal energy storage	Technology
	Micro hydro-generation	Technology

Table 6 >> Domain: Enhanced technologies for infrastructure asset management

TYPES OF METHODS AND TECHNOLOGIES	METHODS AND TECHNOLOGIES FOR IMPROVEMENT COVERED IN TRUST	TECHNOLOGY OR TOOL
Integrated IAM planning	AWARE-P infrastructure asset management approach and software	Tool
Enhanced technologies to support data collection and information management	Mobile software to support asset assessment and repair	Tool
	Pipescanning method for enhanced assessment condition of water pipelines (here pipe scanner BIT)	Technology
Enhanced rehabilitaion technologies	Pipe, sewer and storage tank rehabilitation technologies	Technology

8 Final remarks

The current manual provides a general overview on why IAM is important and the key principles associated to it . Practical implementation very much depends on the level of decision making.

The following volumes of this series provide additional information targeted for different levels of planning and decision making.

If you are a **policy-maker**, you may find recommendations and cases from different countries that may help you in your role in volume “Guidelines for policy-makers”.

If you are utility **CEO** or have a role in strategic planning at the utility level, you are probably interested in volume “IAM strategic planning” where you find guidance on how to develop a strategic plan taking into account IAM concerns.

If you are an **asset manager** and have a role in identifying and designing the best intervention options to meet the strategic objectives and targets of the utility, you may find guidelines and examples in the volume “IAM tactical planning”.

If you are also interested in learning more about different rehabilitation techniques applied to water pipes or to wastewater sewers, you may find interesting going through the volumes “Rehabilitation techniques in drinking water networks” and “Rehabilitation techniques in drainage systems”, respectively.

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