Infrastructure Asset Management – a proposed framework for Norwegian water utilities

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Sammendrag

Rapporten "Investeringsbehov for vann- og avløpssektoren" fra 2013 undersøkte norske vann- og avløpsanlegg med hensyn til fornyelseskostnader og forventede investeringsbehov. Det foreslåtte investeringsbehovet er svært stort og det er nødvendig å etablere et vitenskapelig grunnlag for å begrunne prioriteringene.

I et internasjonalt samarbeid er det laget et rammeverk for å støtte utvikling mot mer bærekraftig vann og avløpsforvaltning. Utgangspunktet for dette er å levere nødvendige VA-tjenester kostnadseffektivt.

Nytteverdien av dette rammeverket er lengre levetid for anleggene og lavere kostnader over levetiden. Gjennomføring krever imildertid god kompetanse og god organisering av vannselskapene.

Abstract

The report "Investment needs in the water and wastewater sector" from 2013 investigates Norway's water and wastewater facilities with respect to replacement costs and estimated investment needs. The suggested investment need in order to cope with lack of infrastructure maintenance is significant and hence arise the need of justifying the priorities scientifically.

Infrastructure asset management (IAM) is a framework to pursue and achieve sustainable infrastructure. It is the practice of managing infrastructure assets to minimize the total cost of owning and operating them while delivering the expected service level.

Infrastructure asset management applied to water utilities gives great benefit in terms of reduced costs and extended service lives. Nevertheless, it is a comprehensive methodology greatly dependent on the personnel executing it, and a successful implementation requires solid foundation within the organization.

Introduction – status of today

The Norwegian water and wastewater pipelines consist of approximately 100 000 km of pipes. Norwegian Water, the national association of water and wastewater works, has stipulated the replacement value of this technical infrastructure to be more than 900 billion NOK.

In 2010 the Norwegian Association of Consulting Engineers (RIF) presented the report "State of the Nation" on condition of Norway's technical constructions, considering both status and ongoing trends. For water supply it is stated that the condition is *"acceptable, but not good"*,

and concluding that "*investments in rehabilitation are necessary*". Out of 11 infrastructure types, wastewater received the lowest marks: «*Poor condition, functionality under threat, immediate efforts recommended to avoid reduced performance*». Further the report states the need of upgrading existing pipelines in order to cope with degradation and impact of climate change, and the need of competence recruitment to manage urban water systems.

Norway's urban water systems are valuable parts of the public infrastructure, and the responsibility of maintaining water services lies on the utilities and municipalities. In addition to meeting the public's demanded level of service they are expected to manage and prepare the infrastructure for future legislations and growing populations.

Water and wastewater infrastructure, being hidden underground, differs from other infrastructure and making management especially challenging; the water services are taken for granted whilst gaining access to assess condition is difficult (sometimes impossible). A consequence of the latter is the water utilities are not always aware of their investment needs, and which assets need urgent attention. Due to lack of understanding the system behavior of the infrastructure and absence of strategic long-term planning, wrong decisions are made.

The Norwegian Water report "Investment needs in the water and wastewater sector" suggests that by 2030 there is a need to spend approximately 290 billion NOK to fulfill the needs in 2030, with respect to coping with the lack of maintenance, meeting climate changes, future population growth and public demands. The value of the infrastructure demand wise spending and innovative, efficient planning.

As water and wastewater utilities all over the world are facing similar challenges there is an increasing focus on urban water cycle services as regards to optimizing the management of these assets. Experienced researchers and experts argue that a good, integrated and strategic asset management approach is essential for maintaining sustainable water supply and wastewater services. There exist several research initiatives to improve the methodology of sustainable infrastructure asset management.

The objective of this paper is to give an introduction to infrastructure asset management and how it may be applied in Norway.

What is Asset Management?

Asset management (AM) is the set of systematic management practices that is applied to the entire portfolio of assets at all levels of an organization. The overall objective is to ensure that legal requirements and customers' expectations are met. This is to be done while minimizing the costs associated with acquiring, operating, maintaining and renewing the assets and maintaining an acceptable level of risk.

Asset management began as a loosely organized set of practices, with development of narrowly focused techniques by separate groups of engineers and materials scientists. Over time, the perspective expanded to the integration of these techniques into a conceptual framework driving management decision-making. Today asset management is a discipline that requires an integrated set of practices supported by information management and technology. The resulting consensus process has over time proven to be highly cost effective.

Infrastructure assets differentiate from other physical assets as they are not to be considered individually, but rather as parts of a system:
"Infrastructure assets are defined functionally as assets that are not replaced as a whole but rather are renewed piecemeal by the replacement of individual components whilst maintaining the function of the system as a whole. Infrastructure assets have indefinite lives. Economic lives, however, can be assigned to individual components of an infrastructure system."
(Burns et al., 1999)

IAM is said to be essential in order to obtain and sustain water supply and wastewater services in long term. It is a scalable approach that may be implemented by systems of any size and quality. Whether running a small drinking water system serving a few customers or the

water supply and wastewater systems of a large city, asset management provides the means to prepare a long-term plan that will maintain these systems and their provided services. Even very good systems benefit from IAM as the contexts of legislations and public demand are continually changing; there is always room for adjustment and improvement.

Infrastructure Asset Management Framework

The concept of IAM may be explained using the structural cube, figure 1. The structure highlights IAM as a multi-dimensional approach not only designing the system but also managing it. The methodology applies at all planning levels; strategic, tactical and operational, considering performance, risk and cost. In order to achieve good asset management the competences of business management, engineering and information are required.

Dimensions of analysis

The primary objective of IAM is to ensure adequate service and low/acceptable risk to the most favorable price in a long-term perspective. It requires multi-objective decision making with the purpose of minimizing life cycle costs and risk whilst maximizing performance. The key is to optimally balance these three factors.

Performance is related to the function of the assets and their expected level of service. A well-defined level of service should include asset performance in objective and measurable terms, and a suitable minimum condition grade in line with the impact of asset failure.

The overall performance may be described as the efficiency of a service; hence, in order to ensure adequate effectiveness, performance assessment is necessary. Performance assessment is conducted by evaluating efficiency using performance measures.

Risk assessment is crucial in strategic plan-

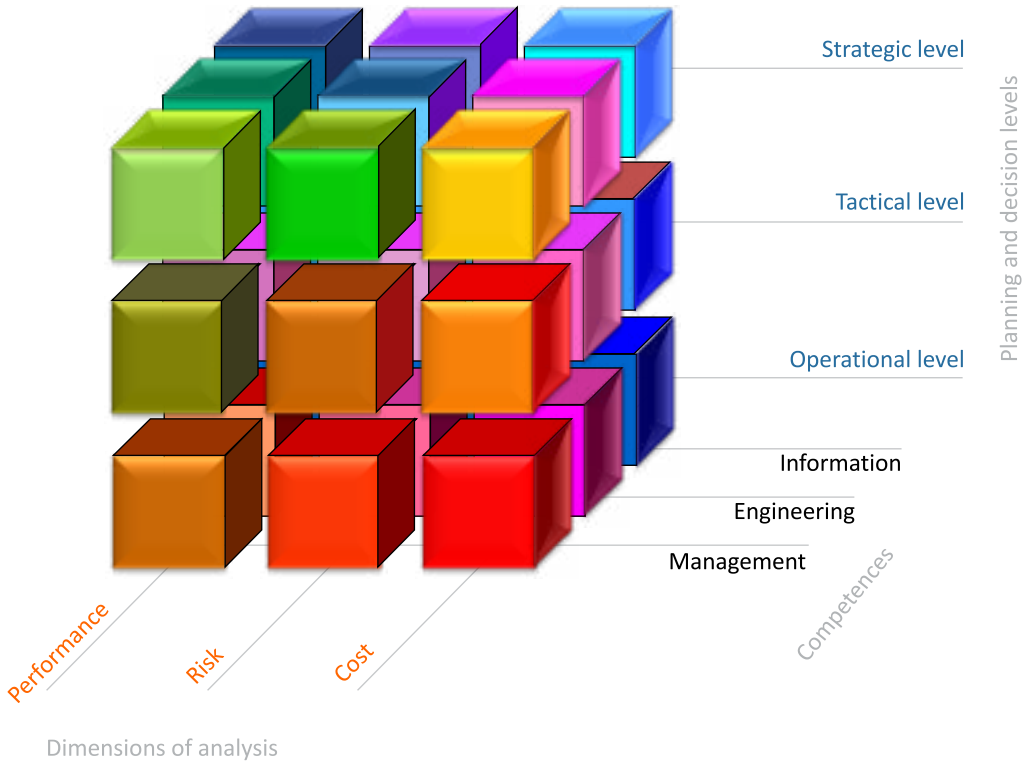

Figure 1. General IAM approach (Alegre, 2012)

ning, pointing out vulnerable and/or vital areas of the infrastructure to be prioritized. According to ISO 31 000:2009 the assessment involves risk identification, risk analysis and risk evaluation.

Risk may include several different dimensions, hereunder health, environment and economy Level of risk for an event is determined by considering expected probability for the event to occur in combination with the associated consequences should the event occur. Usually, the identified events are defined using a risk matrix. The method provides a discrete approximation to a quantitative relation between probability and consequence. The event is placed in the predefined matrix and given (typically) low/acceptable, medium/tolerable or high/unacceptable risk.

Cost assessment is an obvious axis of analysis when selecting intervention alternatives for future investments, operation and maintenance. Cost assessment as a part of IAM considers the life cycle cost of the asset, including investment and operational costs and revenues. It may also include the cost of a potential asset failure.

Strategic, tactical and operational planning – alignment through decisional levels

IAM requires a multi-layer planning structure based on the same objectives, but with different approaches.

First, on a strategic level, the overall goals and the direction in which the organization is aiming at in a long term perspective are set, grounded on the vision and mission. Secondly, when the strategic planning has pointed out a defined direction the tactical planning defines the path of intervention priorities and possible solutions. While the tactical planning aims at ensuring the strategic plans are rightfully selected, the operational level's objective is to execute the plans in the right way. These planning steps together constitute a cycle of feedback and review, an ongoing process to be monitored on a regular basis.

Competences

IAM is a multidisciplinary approach. Consequently, it requires the competences of business management, information management and engineering and it is comprised of many techniques. The selection of maintenance model tools interacts through the decision making process.

On a strategic level (where the planning is aimed at service level to the customers) the requirements of knowledge is on performance and rehabilitation needs and investment plans to obtain aimed standard. The selection of objectives requires a long-term vision and proficient knowledge of both external and internal contexts, as well as ability to select appropriate metrics and define targets that will drive the whole planning effort. The system of metrics and targets is further used to monitor the implementation of strategies and support the periodic review of the plan.

Subsequently, the rehabilitation programs are made on the tactical planning level. The decisions are based on knowledge of system performance according to the contribution of each individual asset in terms of hydraulic capacity and structure. The projects are to be selected and ranked keeping in mind the expected level of service.

The operational planning may be considered a technologic support. The main responsibility is providing databases for the infrastructural network and keeping track of renovation and repair, as well as information regarding the best available technologies for the selected projects and interventions to be executed.

The Norwegian Water report "Guidance for condition mapping and rehabilitation planning of water and wastewater networks" (2013) is recommended for further reading on the IAM methodology and related terms.

How to apply IAM in Norway

Norwegian Water has recently finished a project mapping the current state of sustainability of water cycle services in the Norwegian municipalities; "Sustainable management of the water and wastewater services". Using a questionnaire a selection of representatives for the water utilities was asked about their awareness of sustainability. The results were quite concurrent, and two important acknowledgments were made; the

meaning of the term sustainability is not readily grasped as it is old and "wore out" due to progressive use whilst lacking a grounded definition; on the other hand the participants in the questionnaire show positive attitude and motivation when faced with the possibility of a common framework for assessing the infrastructure of Norwegian water services.

The project emphasizes the great potential in using sustainability as a national strategic platform. Including the framework of IAM to this platform might help the implementation of this management reach most of the Norwegian municipalities. A national initiative on sustainability is expected to contribute to probable benefits in the water industry; improved reputation and increased visibility; new innovations; motivated need for investments; streamlined and increased quality of the water and wastewater services.

Awareness and knowledge

To a certain extent all water utilities perform asset management, thus ranging from reactive repair of malfunctioning equipment to an integrated focus on asset management as a strategy.

There are several ways of approaching asset management; the main ones are outlined by Ugarelli (2008):

- An operative (reactive) approach where repair or maintenance is done only after a failure has occurred, and the solution may be designed specifically for the one particular situation. These decisions are often based on practical experiences. The benefit of this approach is that most assets will reach their full service life, on the other hand the costs may be higher due to service interruption or damage to other assets.
- The inspection (condition based) method based on periodical inspections to determine the performance of the system. The rehabilitation prioritization is based on the found condition of the assets, without evaluating the consequences of failure.
- Proactive (preventive) asset management aims at rehabilitating before a failure event occurs. Often decision support systems are used in order to rehabilitate the assets in an optimal order.
- A predictive (advanced) strategy built on optimizing performance and reliability at the lowest possible life cycle cost. This may be done by using cost-benefit analyses supported by risk assessments. The predicative approach makes it possible to examine whether the service life should be extended by operation or maintenance or if rehabilitation is needed.

Which strategy is the best depends of course on the respective preconditions, but it is in any case important to be aware of the different options and to make an active choice of strategy.

Furthermore, the chosen strategy should be thoroughly communicated to ensure all employees take responsible part in it.

Robust organization

The structural cube, figure 1, shows the importance of not only competences, but also the dimensions of planning and analyses altogether. In order for the IAM framework to function properly the organization needs to undertake a thoughtful structure ensuring internal cooperation, streamlined communication and information flow. A part of this is making sure anyone who might get contacted externally will know which department to address with any request.

This structure emphasizes the need for a new professional profile as qualities such as good communication skills and the ability to see the big picture are more important than before. Recruiters should be aware of this.

When considering the importance of cooperation within the organization, making sure information is collected in the same form for later compare is crucial. Any model on water supply pipes should be possible to combine with the corresponding model of wastewater pipes without adjusting the form of input data. Available data provides important data for setting measurable goals, and when deciding how to balance performance, risk and cost most appropriately.

LEVELS	STRATEGIC	TACTICAL	OPERATIONAL
Scale	Macro	Medium	Detail
Scope	Global system	Subsystems	Groups of components
Type of action	Define direction	Define path	Implement action
Responsible	Asset owner	Asset manager	Head of operations
Results	Strategies	Tactics	Operational plans
Time horizon	Long term (10-20 years)	Medium term (3-5 years)	Short term (1-2 years)

Table 1. properties of the three planning levels (based on Alegre, 2009)

An important factor of planning is to ensure systematic linking between long term thinking and short term acting. Table 1 sums up the contents of the three planning levels, and outlines the differences between the strategic (big picture) and operational (hands on) parts of management. These different sections in the Norwegian municipalities must cooperate and coordinate their work to a much larger extent than what's common practice today.

Cooperation and sharing experiences

The importance of internal cooperation has already been addressed, but the importance of external cooperation such as discussing experiences and sharing solutions should not be underestimated.

If Norwegian Water decides to front a national initiative regarding sustainability in the water industry the framework of IAM could be an appropriate part of the strategy. The scientific work on the topic combined with the practical experience gained in water utilities constitutes a solid foundation for implementation.

A project of interest is Transitions to the Urban Water Services of Tomorrow (TRUST), which is an integrated research project funded by the European Union. Over the course of four years and driven by the need of transformation and the wish to protect natural resources, 30 partners in eleven different countries will research innovations and tools to create a more sustainable water future. The results will be implemented and tested in nine participating different pilot cities or regions, grouped in green cities, water scarcity regions and urban/peri-urban metropolitan areas.

The main purpose of the project is to assist the European water utilities in the task of identifying and implementing policies that safeguard urban water and wastewater services for the future. TRUST generates knowledge contributing to ensure that these services are sustainable without compromising the quality.

The project is at its 4th year. One of the most challenging and important achievements so far is the common definition of sustainability over which the whole project is built. In addition software, road mapping approaches and optimization tools have been developed but they are still on a calibration, testing level.

In general the assessed intervention options focus on improved planning and more sustainable operation of urban water cycle services (UWCS): Optimization of water and wastewater treatment plants, transport, on demand and leakage reduction, management of severe storm water events, on preparing wastewater treatment systems for water reuse, increasing energy efficiency in all parts of the water cycle as well as utilizing the potential for combined heat and power generation and the use of alternative water sources (such as reuse of wastewater/storm water, desalination).

In the area of infrastructure asset management, priority is given to innovative localization, inspection and visualization techniques and the development of sustainable rehabilitation concepts. In total, 34 technical intervention options, covering tools, supporting planning processes

and technologies like heat and cold recovery from the water cycle system have been assessed.

The framework of IAM has already been introduced in Norway's capital, Oslo. IAM was conducted as the Water and Wastewater works (Oslo VAV) reviewed their master plan for wastewater networks for the period of 2015-2030. By using condition assessment to estimate how the different groups of pipes will deteriorate VAV set up a strategic plan for maintaining their wastewater pipe network. The process is discussed in the paper "*Wastewater pipes in Oslo: from condition monitoring to rehabilitation planning*" (Ugarelli et al, 2013).

The following research questions were addressed:

At strategic level: how much should VAV spend to improve the structural conditions of the network?

At tactical level: what pipe to rehabilitate first, and when?

In order to identify the proper long term rehabilitation rate four scenarios were tested. The scenarios were selected on basis of discrete distribution of pipe classes compared to a "do nothing"-scenario (the pipe classes 1-5 were defined according to the Norwegian Water-report 196/2013 on condition assessment). For instance, it was found that a rehabilitation rate of 1.5% yearly until 2030 was required in order to achieve a maximum of 10% of pipes in condition class 5. The rehabilitation rate was set to 1.6 %.

Subsequently, the following step aimed at prioritizing pipes to be included in the yearly rehabilitation. Inspected pipes were placed in a risk matrix and given priority order to be rehabilitated. The not inspected pipes were prioritized for inspection.

Furthermore, there is good reason to gain experience from the Portuguese project "Moving IAM from science to industry". The collaborative project took place in April 2012-October 2013, through which the development of individual IAM systems and plans were made possible in 19 Portuguese water utilities. Portugal's National Civil Engineering Laboratory (LNEC), Technical University of Lisbon (IST) and the software development company Addition ensured the utilities technical assistance both in collective training and in individual support.

The project followed the IAM planning methodology of AWARE-P. The AWARE-P methodology incorporates the IAM principles as discussed earlier in this paper and presented in figure 1 (the cube). The defined management process of AWARE-P is built on the four phases Plan-Do-Check-Act (PDCA) to be repeated in a continuous improvement loop. The process is applied at strategic, tactical and operational level striving for alignment of set objectives and measurable targets between levels.

The greatest challenge was said to occur as the utilities were to choose objectives, measurement criteria and corresponding metrics in their plans. The process differs from the established practice where metrics are used mainly as final compliance checks. However, the utilities benefited from the project group dynamics learning from one another through the process and were all able to develop consistent systems of objectives with corresponding metrics.

The variety of participating utilities in the project demonstrates that IAM may be successfully implemented in many different contexts if done systematically with proper technical assistance. In this case the utilities benefited from the simultaneous process as occurring challenges were addressed differently leading to an effective sharing of solutions, and a more effective cultural change.

The implementation of IAM to urban water systems tends to require a shift of mind-set for the parts involved, and the collaborative project format has been found appropriate in this kind of situation.

Discussion

The ability of a water utility to perform a satisfactory and sustainable water service is dependent on numerous human, institutional and financial elements. Moreover, the demand for urban water services is increasing from both customers and government while crucial personnel are retiring. From a utility's perspective it is difficult to

achieve long term objective on these terms at the same time as the infrastructure is ageing and deteriorating.

Imagine a water utility where everyone knows *what* to do in order to obtain the most sustainable asset management. They know *why* they should do it and *how* it is important to the rest of the organization. Thus, they feel *proud* because they are doing what is best for their infrastructure, for their customers and for the environment in the long term.

IAM represents a transition from building and operating the assets to managing them. Hence; it is a framework setting already existing tasks into a structured co-dependent system with the objective of extending the asset life, optimizing maintenance and renewal, and ensuring accurate long-term investments. Most utilities are already equipped with the necessary functions for a successful implementation of IAM. The challenge is to set all these functions into a thoughtful structure and rebuild organizations to ensure aligned planning and optimization.

Previous studies conclude that adaptation to the AM framework requires an internal process. The organization need to undertake implementation by including and informing everyone. In some utilities all functions are care taken by one single employee, whilst in other the organization consists of (several) hundred people. Regardless the size it is important to establish acknowledgement of asset management as a beneficial multi-objective methodology. The key to achieve a successful business practice is to use the human resources.

According to the findings of Norwegian Water's project "Sustainable management of the water and wastewater services" there is a substantial motivation for implementing a more comprehensive management strategy. Consequently, it seems reasonable to assume the utilities will (greatly) benefit from implementing the infrastructure asset management framework if given proper education and time to mature their knowledge.

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