NTNU – Trondheim
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Maintaining Sustainable Water Services

Embedding infrastructure asset management in a medium Norwegian water utility - a demo case study approach

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ABSTRACT

The urban water infrastructure assets embodies a large portion of the total value of all public infrastructures, and is fundamental for good living conditions. The replacement value of the infrastructure in Norway alone is more than 500 billion Norwegian kroner. An aging infrastructure combined with shifting external conditions has resulted in a change from mainly investing in new infrastructure to manage and rehabilitate existing assets. With strong indications that the water utilities are facing challenges when it comes to their water infrastructure, the focus on asset management (AM) is growing. AM in the water sector can be described as managing infrastructure capital assets to minimize the total cost of owning and operating them, while also delivering a satisfactory service level for the customers.

Experienced experts and researchers argue that a good, integrated and strategic AM approach is essential for the maintenance of sustainable water supply and wastewater services. There exist several research initiatives to improve the AM for water utilities. However, the use of integrated or strategic AM approaches and use of tools and models does not seem to have spread in the expected degree, particularly not to small or medium sized water utilities or companies. In order to contribute to the knowledge of key conditions for successful dissemination of infrastructure asset management (IAM) approaches to smaller and medium sized water providers, this thesis will look at embedding IAM in a medium water utility by testing one of the latest and well acknowledged IAM research initiatives, the AWARE-P project, in a demo case study.

This implies operationalizing the AWARE-P concept with the use of a carefully defined set of hallmarks, explore and understand the actual situation in the demo case water utility by reviewing planning documents and meeting with key personnel, describe and recognize why there is a gap between actual practise and the recommended AM approach advocated by AWARE-P, to understand why the utility decides to do what they do today, and then finally use this knowledge to test the implementation of key elements in the recommended AM approach. This is done to find: a) what type of problems are we facing with implementation, b) what type of benefits can this implementation give a water utility and c) understand the kind of characteristics or qualities that need to be present in AM methodology and tools in order for successful implementation and use. This is done at two stages, an applied analysis to test key elements at the tactical level and a simulated process for testing at the strategic level.

The closing chapter focuses on the lessons learned from the demo case study approach and discuss ways forward to enable better implementation and more wide spread use of high quality integrated IAM approaches in small to medium sized Norwegian water utilities. This includes approaches to lowering the threshold for use, e.g. compensating for missing data, and a demonstration of a decision theatre approach that can support a water utility in their planning process and thus motivate for improved use of analytical tools, decision support systems and at large achieve a more structured and comprehensive IAM practise.

SAMMENDRAG NORSK/NORWEGIAN

Verdien av infrastrukturen for vann og avløp utgjør en meget stor andel av den totale offentlige infrastrukturen, og er helt grunnleggende for gode levevilkår i et samfunn.. Bare for Norge er gjenanskaffelsesverdien for denne infrastrukturen på mer enn 500 milliarder norske kroner. En aldrende infrastruktur kombinert med skiftende ytre forhold har resultert i at man i stor grad har måttet endre fokuset fra investeringer i ny infrastruktur til å forvalte og rehabilitere eksisterende eiendeler. Med klare indikasjoner på at våre vannverk nå møter store utfordringer med å opprettholde gode VA-systemer, har det blitt nødvendig med et økt fokus på god forvaltning av eksisterende ressurser. Verdiforvaltning i vannsektoren kan defineres som vedlikehold av infrastruktur og forvaltning av investert kapital med sikte på å minimere samlede kostnader ved å eie og drifte anlegget, samtidig som man leverer et tilfredsstillende servicenivå til forbrukeren.

Erfarne fagfolk og forskere argumenterer for at en god forvaltning- og rehabiliteringsprosess er avgjørende for å skape og opprettholde bærekraftige VA-systemer. Med et mål om å forbedre slike prosesser i vannverkene og trekke dem mot mer integrerte og strategiske planleggingsprosesser, har det blitt satt i gang flere ulike forskningsprosjekter. Likevel ser det ikke ut til at vi finner noen stor utbredelse og bruk av disse nyutviklede metodene og tilnærmingene i praksis. Dette gjelder spesielt for de små til mellomstore vannverkene. For å bidra til å forstå nøkkelforutsetningene for en større og bedre spredning av ulike forvaltnings-, rehabiliterings- og planleggingstilnærminger, vil denne oppgaven se på hvordan dette kan innlemmes i et mellomstort norsk vannverk ved å teste bruken av et av de nyeste og godt anerkjente forskningsinitiativene, AWARE-P, i et demonstrasjons casestudie.

Det vil innebære å operasjonalisere AWARE-P konseptet ved å definere et presist sett av kjennetegn, undersøke og forstå situasjonen i casestudie vannverket, ved å gå gjennom planleggingsdokumenter og intervjue nøkkelpersoner og deretter beskrive hvorfor det er et gap mellom faktisk praksis og den anbefalte tilnærmingen til AWARE-P. Videre vil det handle om å forstå hvorfor vannverket jobber slik de gjør i dag og tilslutt bruke denne kunnskapen til å teste implementering av den anbefalte praksisen til AWARE-P. Dette gjøres for å finne: a) hvilke problemer står man overfor ved en implementering, b) hvilke fordeler kan et vannverk ha ved å implementere denne tilnærmingen og c) forstå hvilke kjennetegn eller kvaliteter som trengs i forvaltnings-, rehabiliterings- og planleggingsmetoder og verktøy for vellykket implementering. Dette er gjort i to steg, først en anvendt analyse for å teste noen viktige elementer på det taktiske planleggingsnivået og deretteren simulert prosess for testing på det strategiske nivået.

Det avsluttende kapitelet fokuserer på hva vi har lært fra casestudien og en diskusjon av mulige veier fremover for lettere implementering og økt bruk av gode og integrerte verdiforvaltningsprosesser i små og mellomstore norske vannverk. Dette inkluderer for det første å senke terskelen for bruk, f.eks. ved å kompensere for manglende data. For det andre en demonstrasjon av et mulig beslutningsverktøy for å støtte opp om den eksisterende planleggingsprosessen og gjennom det søke å motivere for økt bruk av analytiske verktøy og større allmen bruk av mer strukturert og helhetlige verdiforvaltnings- og planleggingsprosesser.

PREFACE AND ACKNOWLEDGMENTS

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Gard N. Reichborn

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1.1 WATER INFRASTRUCTURE CHALLENGES

Water is the single most essential element for all life. Safe and sufficient supply of water is indispensable for good living conditions. This of course includes drinking water, but also for many other important aspects like sanitary conditions, personal hygiene, food production, industry or recreation. Our society is totally dependent on good water and wastewater infrastructure. One can just imagine a day without any of these services. In average, the consumption per person per day in Europe is 200 litres (Killingtveit, 2009).

In Norway, we are lucky with an abundant supply of surface water that is able to meet our needs. Most people in Norway have access to relatively good and clean tap water through a municipal or intermunicipal water provider (Ødegaard, 2009). However, this is not to say we are not facing great challenges when it comes to sustaining or improving our water supply in the future.

The urban water infrastructure assets embody a large portion of the total value of all public infrastructures (Cardoso, et al., 2012). In Norway, we have close to 1600 water utilities with 47 000 km of main drinking water supply pipes and around 50 000 km of wastewater pipes. The replacement value totals 500 billion Norwegian kroner and has a turnover of around 10 billion per year with 6000 employees (Kjenseth, 2011). This combined with the essentialness of the urban water infrastructure, makes this sector an important part to focus on in our society.

Water utilities today are facing several challenges when it comes to providing good services to the customers and maintaining the quality of the urban water infrastructure. This includes population growth, urbanisation or other demographic changes, stricter government legislation and lack of access to good quality raw water. However, one of the main challenges in developed countries relates to an aging infrastructure (Allbee, 2009).

United States Environmental Protection Agency, Office of Water has looked at the implications of aging infrastructure and the fact that a substantial share of present pipes where installed in the 1950's and 60's. Figure 1 illustrates the challenge.

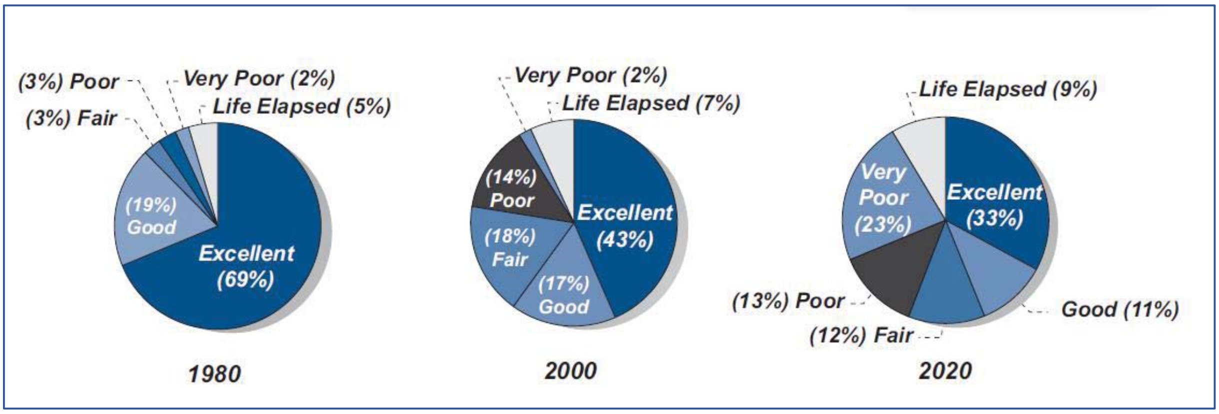


Figure 1 Assessment of pipe condition over time [percentage of pipe by classification] (US EPA, 2002)

From these charts, one can see that the condition of the pipes has gone from a large predominance of pipes in excellent condition in 1980, to a situation where a third of the pipes is in very poor condition or has actually reached the end of their service life. This shows that the water supply and wastewater sector has a tremendous task in front of them to be able to maintain a sustainable water network. Even though this particular study is performed in North America, other reports from Europe, (Allbee, 2009), (Carrico, et al., 2012) and (Marques, et al., 2012), shows the same picture.

There is no reason to believe that this is not also applicable for Norway. For instance, a published overview from Stavanger municipality outlined the following: The first pipes were installed in 1865 and pipes from this period are still in use. In Stavanger, the average pipe age is 34 years, because their main development and installation period is 10-15 years behind the data reported by US EPA, but otherwise the main pattern seems identical (Stavanger Kommune, n.d.). Without an increasing renewal rate it is possible to predict the same pattern as in figure 1, subject to selection of pipematerials.

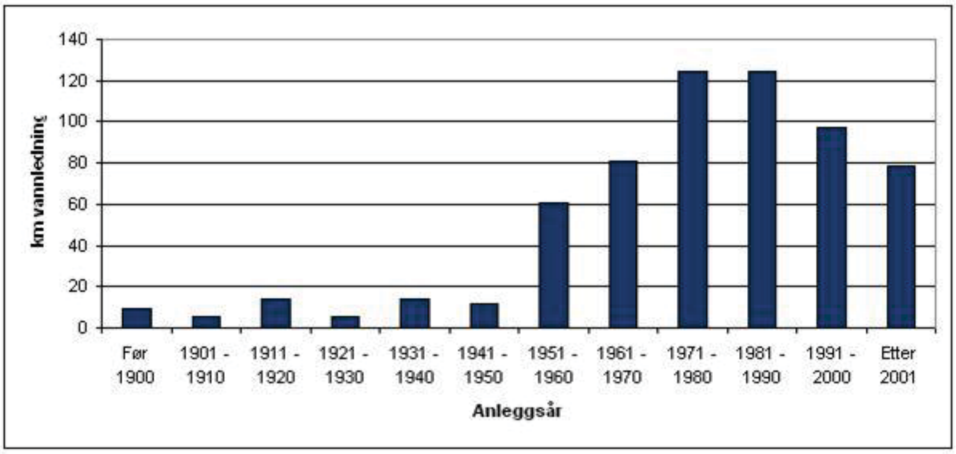


Figure 2 Pipe installations in a Norwegian city, Stavanger (Stavanger Kommune, u.d.)

In a report from the Norwegian Institutte of Public Health there is shown an overview of the age of the water supply network in Norway from 2003 to 2007 (Myrstad, et al., 2011), see figure 3. This shows some of the same characteristics as in Stavanger, with the majority of the pipes laid between 1971 and 2000. It does however also show that the percentage of pipes laid in this periode is decreasing, meaning that the process of replacing these pipes has started.

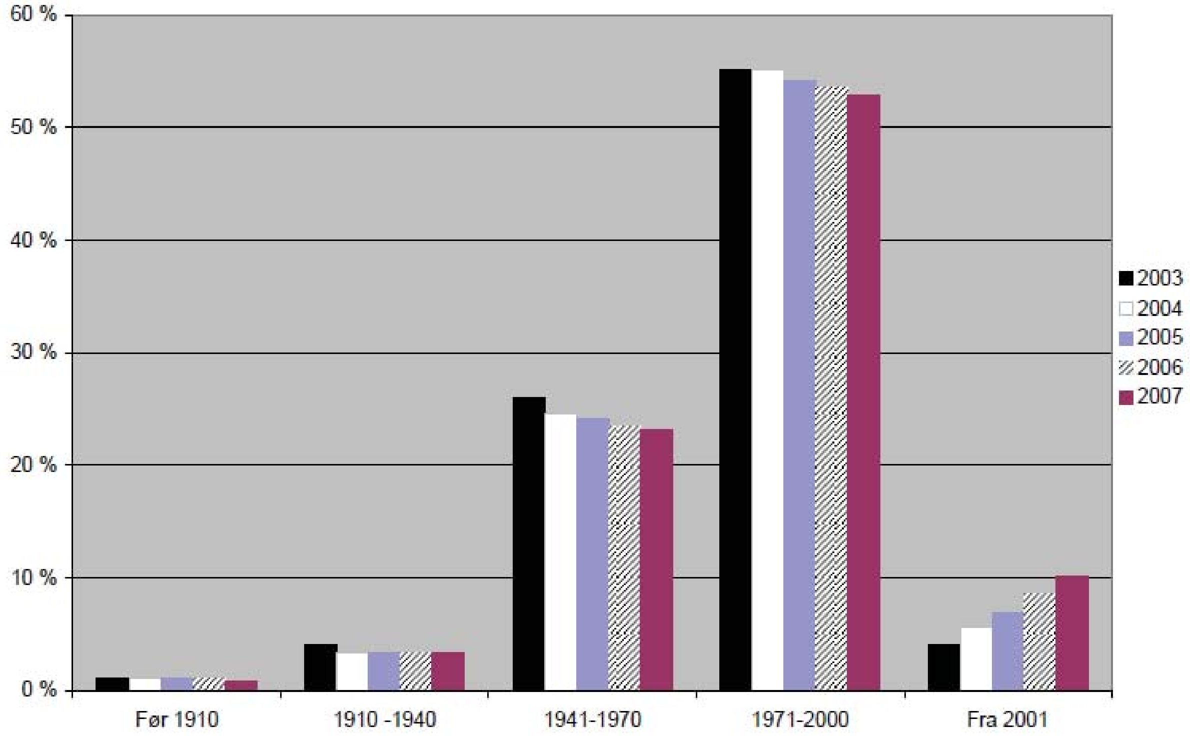


Figure 3 Construction period shown as percentage of total length of pipes from 2003 to 2007 (Myrstad, et al., 2011)

NOU 1994:12 Lov om vassdrag og grunnvann, sums up the overall situation as follows (note that this report is from 1994, meaning that the percentage ratio is not identical to what is presented in figure 3): 7% of the infrastructure is from before 1900. The bulk was installed in the first decades after the Second World War, with a frequent use of asbestos cement pipes with known problems and poor durability. A loss with a leak percentage in the area of 40-50% can largely be explained by implications from this installation wave (Vassdragslovutvalget, 1994). A known renewal rate in Norway of 0,8 percent for water supply pipes (Aasand, 2011) do not indicate a situation in Norway that is significantly different from the international studies referred above.

Therefore, it is naturally to assume that Norway is facing many of the same challenges that are seen in other developed countries. Around a third of the water supply and wastewater pipes is built with material and installation technologies that are not acceptable today (Sægrov, 2012). This constitutes around 30 000 km of pipes. To renew the oldest part of the pipeline network in Norway, that does not meet the requirements today, will cost more than 50 billion Norwegian kroner. In addition, climate change and urbanization are aspects that will also affect Norway. For example, there is to be expected a population growth in the major cities of around 20 – 30% (Sægrov, 2012).

The investment needed to solve these challenges will of course not be possible to realize in the matter of a few years. However, it is also not sustainable to transfer these responsibilities to the next generations. A strengthened focus on renewal and increase of water capacities needed is therefore important. According to Sægrov, 2012, the renewal of the pipeline network in Norway is one of the largest tasks the water and wastewater sector is facing. It is therefore necessary to have the tools, models and knowledge at their disposal in order to make the best planning and rehabilitation decisions.

1.2 MEETING THE CHALLENGES

Since all indications tell that the water utilities are indeed facing problems or challenges when it comes to water infrastructure, it is natural that the focus on asset management is growing (Schulting & Alegre, 2009). Asset management in the water sector can in short be described as *"managing infrastructure capital assets to minimize the total cost of owning and operating them, while also delivering a satisfactory service level for the customers"* (Schulting & Alegre, 2009).

To a certain degree, every water utility performs a type of asset management. This can range from just reactive repair of malfunctioning equipment to a more integrated and deeper focus on an asset management strategy. Either way, a good and integrated asset management approach is argued to be essential for the creation of sustainable water supply and wastewater services (Schulting & Alegre, 2009). In recent years, there has been a greater focus on asset management and the importance of good asset management with several initiatives or projects aiming at improving the asset management practices used (Schulting & Alegre, 2009). This includes for example major initiatives like CARE-W, TRUST, SIROCO and AWARE-P, which will be described in more detail later in the report.

However, in spite of the development of the art of asset management for water utilities, a wider use of integrated or strategic asset management approaches and use of tools and models does not seem to have spread in a large degree to the average water utility or company. To the extent that such practices are implemented it is, not surprisingly, more likely to find them in larger water utilities than in medium and small utilities (Schulting & Alegre, 2009).

It is however, not likely that one will be able to meet the challenges described above if not the large number of medium sized and smaller providers are included. In this context, it is therefore important to explore and understand planning and asset management practices in those utilities. Without them, the challenges will hardly be met.

1.3 SCOPE OF THESIS

In order to contribute to the knowledge of key conditions for successful dissemination of infrastructure asset management (IAM) approaches to smaller and medium sized water providers, this thesis will look at embedding infrastructure asset management in a medium water utility. The approach will be to reveal and discuss the inherent content and requirements from structured approaches and then test application and benefits in an actual organization to discover fits and misfits, pros and cons. Lessons learned from the case study will be utilized in a discussion of what it will take from the utility side to move towards a more integrated approach to asset management and, equally important, what kind of amendments or development issues should structured approaches carefully look at if they have the ambition to ease the implementation and common use in this segment of the industry.

1.4 INTRODUCING THE CASE UTILITY

In cooperation with the DiVA project, the water utlity in Oppegård municipality was selected for the case study. As will be documented and discussed in detail later, there are at the present noticeable differences between recommended asset management practices and used practices in this case. There is also no particular reason to believe that Oppegård deviates significantly from the main asset management pattern in other municipally operated water ultilities in Norway. For example, the interest group for water and wastewater in Norway, Norsk Vann, has done a condition evaluation of Norwegian municipalities' water and wastewater services, see appendix 1. This condition evaluation shows no clear or significant deviation from other municipalities.

To verify that the asset management pattern in other municipally operated water ultilities in Norway do not deviate significantly from our case utility, a review of published planning documents from a small randomly selected sample of municipally owned and operated utilities is conducted.

1.4 A SPOT CHECK OF THE AM SITUATION IN OTHER SMALL AND MEDIUM SIZED NORWEGIAN WATER UTILITIES

Planning and legislative documents for municipalities in Norway are supposed to be made available to the public, and it is therefore possible to do a high level review for some of the municipal water utilities and evaluate the approach and content in their planning documentation to get indices of their asset management practises. Within this publication practices it is assumed that unpublished work documents and actual practices will not deviate significantly from the formal and published documents regarding approaches, themes and main directions of efforts and objectives, at least not in the sense that the unpublished should be far more structured and comprehensive.

The municipalities randomly chosen within the segment are Notodden, Molde and Rælingen. These three municipalitites also fits the label of "small to medium sized" water utilities. After the selection, a search for published planning documents was done.

It was found community master plans in the water provision area for both Molde and Rælingen. For Notodden on the other hand, no planning documentation covering this part of their activities was found. They have a fairly exiensive list of "current plans and strategies". However, no water supply and wastewater master plan or rehabilitation plans were included (Notodden

Kommune, 2012). In the planning documents for Molde and Rælingen they recognise some of their challenges, and set goals for how to achieve a good and satisfactory water supply. Amongst these goals are reduction of water losses and improvement of their GIS systems with better registration of events (Colbjørnsen, et al., 2011).

In the master plan for Molde (Molde Vann og Avløp KF, 2010) they have a relatively good overview of their network and are recognizing the problems with especially old grey cast iron pipes and their need to rehabilitate parts of their network. There is also some use of hydraulic modelling in the form of Epanet to optimize their network and choosing best dimensions for new pipes. However, it is not found a wide use of analytical tools or prediction models that enables a choosing of the best intervention solutions or a more comprehensive asset management plan where different solutions is compared for different aspects such as performance, risk and cost. Some of the same observations are done for Rælingen municipality.

These findings are of course not substantial enough to make a final judgement of the water utilities in Norway and their asset management and planning approaches. However, it serves as an indication of a certain gap between recommended and actual practices and that the findings in Oppegård are not untypical. It is important to stress that this is an evaluation of asset approach, and not a judgement of decisions and priorities in the actual cases. Nonetheless, since "experts in the water supply and wastewater community" are stressing the need for better, integrated water infrastructure asset management, it is reason to believe that there is room for a significant improvement.

2 ASSET MANAGEMENT THEORY AND APPROACHES

2.1 DEFINITION AND OVERVIEW

When discussing infrastructure asset management (IAM) it is important to first have a clear understanding of what defines an asset, as well as an idea of what asset management (AM) actually is.

OECD provides the following definition of assets:

"Assets are entities functioning as stores of value and over which ownership rights are enforced by institutional units, individually or collectively, and from which economic benefits may be derived by their owners by holding them, or using them, over a period of time" (OECD, 2003)

This definition implies that an asset is any property belonging to an organisation or individual that in itself has value while also generating revenue. Looking at infrastructure assets, it is possible to see that these differ from other capital assets in some ways. Maybe a better definition for infrastructural assets is the one given by Burns et al. (1999):

"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."

What is important to remember in this aspect is that infrastructure assets must not be looked at as a set of individual assets, but rather as *systems*. Systems that have indefinite lives with changing target performance depending on the evolution of service needs and available technology (Alegre, 2009). What this eventually leads to is that the aim of rehabilitation will not be to regain the initial characteristics, but rather providing the required characteristics so the infrastructure will perform according to the actual needs and expectations (Alegre, 2009).

For asset management, several different definitions exists. These range from broad statements such as "asset management = utility management" to more narrow definitions such as "Asset management is a systematic process of maintaining, upgrading, and operating physical assets cost effectively" (Alegre, et al., 2006). Each of them trying to summarize the essence of what AM is. However, the most fitting definition is perhaps the one provided by Brown & Humphrey (2005):

"Asset management is the art of balancing performance, cost and risk. Achieving this balance requires support from three pillars of competency: management, engineering and information"

This definition goes a long way in suggesting that asset management is far from an exact science. It does however also give the three most important objectives for asset management; 1) optimize performance, 2) minimize cost and 3) minimize risk.

The ability of a water utility to perform a satisfactory and sustainable water service is dependent on not only the infrastructure in itself, but also numerous human, institutional and financial elements. DWAF (2008) depicts the key elements to ensure a sustainable water service delivery in figure 4 below.

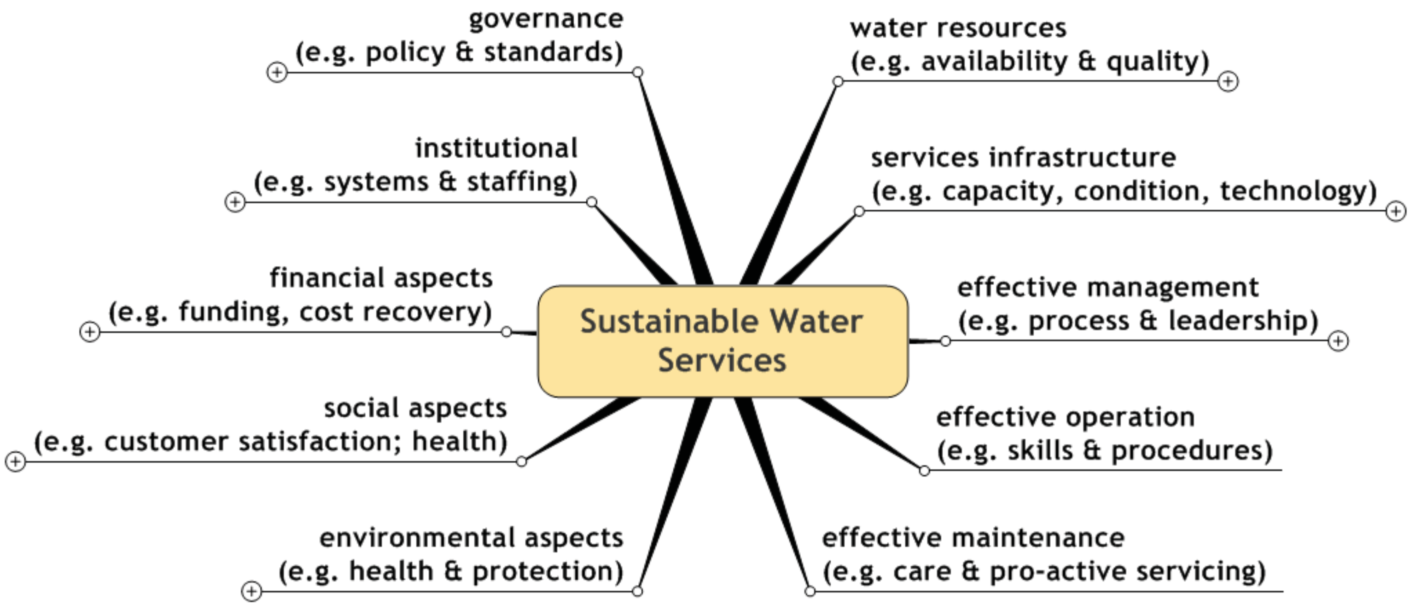


Figure 4 Key elements for sustainable water service (DWAF, 2008)

IAM is the science of combining management, financial aspects, engineering, economics and social practices and techniques within a coherent management framework and asset management plan and process (DWAF, 2008).

For IAM it is often referred to three planning stages or levels: Strategic level (long term planning), tactical level (prioritizing of projects) and operational planning (selecting best technology) (Sægrov, 2012).

1. **Strategic level.** The aim for this level is to set the general direction for the water utility as well as defining goals and objectives. This will include the financial needs, the desired or required service level as well as the general performance of the network. Strategic planning is done on a macro-scale and looking at the total network system. The planning horizon is long term typical 10-20 years. (Alegre & Covas, n.d.).
2. **Tactical level.** Based on the results from the strategic planning, the individual assets are evaluated and then the different alternatives to accomplishing the objectives from the strategic level are assessed. This tactical plan will then give a prioritizing of projects, what assets need to be rehabilitated or renewed. The time horizon is typical 3-5 years (Alegre & Covas, n.d.).
3. **Operational level.** When the projects have been selected at the tactical level, the best technology to realize the projects has to be ascertained. Operational planning will give a description of how the projects will be realized. The time horizon is typical 1-2 years (Alegre & Covas, n.d.).

The hierarchy between these different levels in the management process are presented in figure 5.

Figure 5 Hierarchy of the management process (Alegre, 2009)

To be able to have a good, reliable, efficient and strategic IAM plan, it is necessary to plan and coordinate on all three levels (Ugarelli, 2007). Water infrastructure asset management is also a multidisciplinary approach that requires competences in engineering as well as management and information. Figure 6 gives a comprehensive list and definition of the most important aspects of IAM.

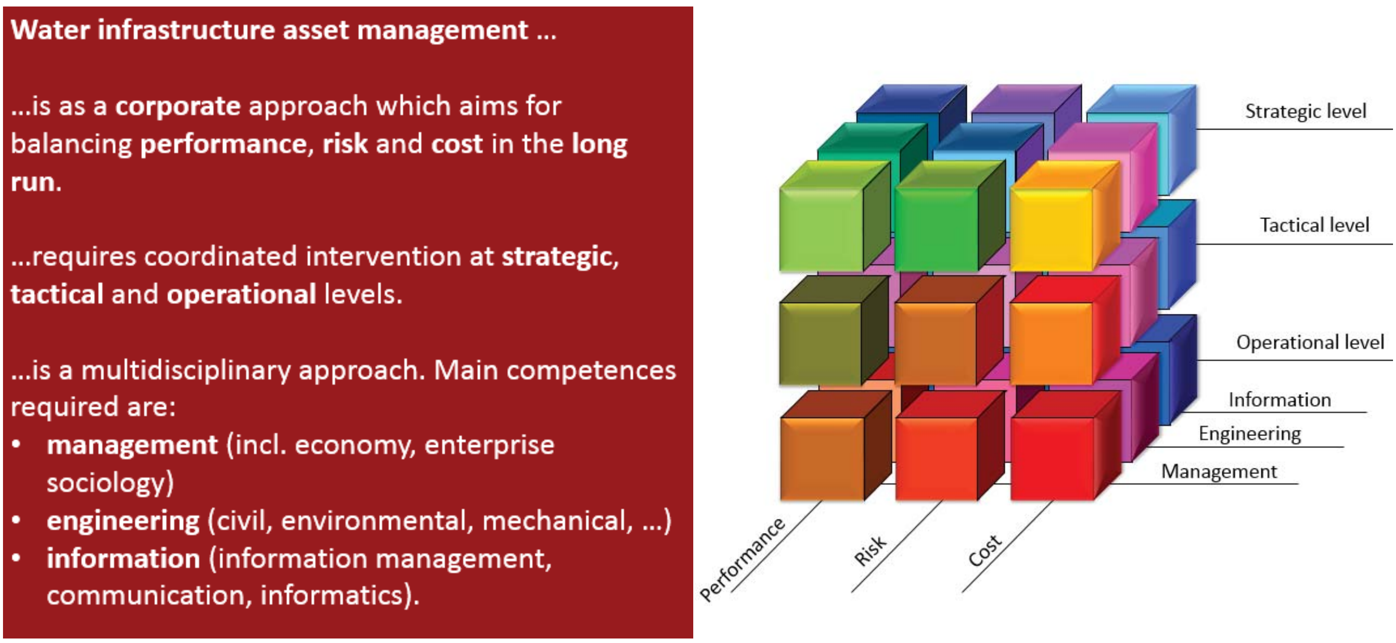


Figure 6 Three dimensions of IAM (Ugarelli, 2011)

In the previous definition from Brown & Humphrey (2005) three important aspects to AM are presented; performance, risk and cost. Since these concepts are such key elements in AM, it might be beneficial to explain and define them properly.

Performance is the ability to successfully perform the required functions. This means that an asset which fulfil its functions and complies with the desired level of service is performing well (Rokstad, 2012). One way of monitoring and comparing performances between different water utilities is by the use of *Performance Indicators* (PI) (Rokstad, 2012). Alegre et al. (2006) has proposed the following grouping of performance indicators:

- Water resources
- Personnel
- Physical
- Operational
- Quality of service
- Economic and financial

This structure is proposed so that the PI makes sense for every utility and all types of uses of the system. In addition, these main groups are intended to help identifying the purpose of a certain indicator (Alegre, et al., 2006).

Risk can be defined as "*the combination of the probability of an event and its consequences*" (IRM, 2002). The risk severity or its consequences can include several different dimensions, such as human life or health, environmental indicators or monetary value (Rokstad, 2012).

Cost in regards to AM is often referred to as the life cycle cost (LCC) of the asset. This includes the direct and indirect cost of acquiring, insuring, inspecting, maintaining, repairing and decommissioning the asset (Rokstad, 2012). It can also include the cost of a potential asset failure.

There are several different ways of approaching asset management and engineers employ different methods of managing infrastructures asset. However, Ugarelli (2008) outlines what is called the traditional AM strategies:

- Operative – reactive
- Inspection – condition based
- Proactive – preventive
- Predictive – advanced

An **Operative** approach means that the repair or maintenance is done only after a failure has occurred. Often as *ad hoc* decision, meaning that the decision or solution is designed specifically for one particular situation. These decisions are often based on practical experiences. The positive effect of this approach is that for example a pipe will realize its full service life. The drawbacks of this approach include a possible higher repair cost compared to repairing or replacing before failure or unforeseen extra costs due to effects of the failure, e.g.

service interruption or damage to other properties or assets. In addition, it will result in difficulties in planning due to uncertainties about upcoming failure events.

The **Inspection** method is based on periodical inspections to determine the performance of the system and then do a rehabilitation prioritisation based on the condition of the assets. This method only describes the current situation of the asset, there is no evaluation of the consequences for failure.

Proactive asset management seeks to rehabilitate before a failure event occurs. This will typically involve use of decision support systems (DSS) to better being able to rehabilitate the correct pipe at the right time the most efficient way. DSS can provide different tools where hydraulic, environmental and structural conditions of the network can be assessed and evaluated.

A **Predicative** strategy is built on optimising performance and reliability at the lowest possible life cycle cost. This can be done by the use of cost-benefit analyses supported by risk assessments. The predicative approach makes it possible to examine if the service life can be extended by operation or maintenance or if rehabilitation is needed.

There exist several different approaches to and work methods for asset management. A more operational approach as well as a good starting point or roadmap to understand what is needed to manage assets is the "Six Whats of AM" (Vanier, et al., 2006):

Table 1 Six Whats of AM (Rokstad, 2012)

• *What do you own, and where is it?*	Water utilities usually keep track of what they own through an asset registry (an inventory), for instance a GIS database. An asset database can contain spatial data (the positions of the assets), material, producer, dimensions, time of installation
• *What is it worth?*	Many water utilities use the historical cost of acquiring the asset, appreciated from year of installation to current value. The value however, might also be expressed as the cost of replacing it (capital replacement value), or the cost of the loss experienced if the asset was not to fulfil its function. Vanier et. al. (2006) suggests that a comprehensive asset management system should have at least two different valuation methods of the assets. If the appreciated historical cost is used, the data required from the asset is the time of installation, the installation cost and the depreciation period.
• *What is deferred?*	The cost of bringing the asset back to its original potential is called the deferred maintenance. To be able to assess the deferred maintenance, one must both keep track of the cost of maintenance that has been executed

	and the effect the deferred maintenance has on the value of the infrastructure. Deferred maintenance can be evaluated with respect to several dimensions, such as infrastructure value index and functionality/performance.
• *What is the condition?*	Assessment of an asset's condition can be viewed as an extension of the assessment of deferred maintenance, where the deferred maintenance is expressed through the deterioration of the condition. In order to assess the condition of infrastructure assets, one needs a record of failures (reliability) and/or a record of inspections. There exist non-destructive ways of assessing the condition of a water distribution infrastructure, the most common is leakage detection methods. Reliability is often used as a measure of the water supply network's condition. US EPA (2008) suggest that the condition of assets should be detected and recorded through a condition assessment system.
• *What is the remaining service life?*	The remaining service life is referred to as the technical and the economic service life of an asset, both requiring different data to assess. Remaining technical service life means the remaining period the asset can fulfil its function, while remaining economic service life means the remaining period in which asset maintenance is less costly than capital renewal.
• *What do you fix first?*	It is argued that the better answers (information) one has obtained for the five previous questions, the better one is able to answer the final question: What do you fix first? If the asset manager knows what the utility owns, decisions will be made based on the complete array of assets, but still on subjective evaluations of the individual asset's need for renewal; if the value and condition is known, the decisions will be made on these rationales, and so forth.

Looking at and reviewing the "Six Whats" of AM it is easy to see that available data is essential for good asset management. A lack of relevant and reliable data will seriously limit a water utility's ability to implement a high level of AM. To be able to achieve a high level of AM it is required an array of different data, keeping track of the physical condition, the value and the cost associated with the asset while also being dependent on data over a certain observation period (Rokstad, 2012).

An assertion from Halfawy and Figueroa (2006) summarise AM reliance on data:

"Successful implementation of asset management strategies largely depends on: (1) the efficiency to share, access, and manage the asset life-cycle data; and (2) the ability to efficiently support and coordinate the multi-disciplinary work processes at the operational and strategic levels."

2.2 MAIN ASSET MANAGEMENT INITIATIVES WITHIN THE WATER DISTRIBUTION INDUSTRY

To be able to handle and deal with the challenges concerning working with AM and be able to make the right decisions on how to best maintain the water infrastructure, there exist several different initiatives with various focus on different approaches to AM. This includes emphasis on the use of models or data collection and specific analysis tools. This chapter will focus on presenting four of the main initiatives for AM of water distribution systems.

2.2.1 CARE-W

CARE-W (Computer Aided Rehabilitation of Water Networks) is a project started in 2001 that deals with the public water supply networks and their problems with an ageing infrastructure (SINTEF, n.d.). This includes challenges such as structural failures, insufficiencies and leakages (affecting hydraulic reliability), deteriorating water quality and increasing maintenance costs. These are all difficulties affecting many European and Norwegian water utilities, and the aim of CARE-W was to support European water utilities in their decisions on upgrading water supply (Sægrov, n.d.).

With cities across Europe in 2008 spending in total around one billion euro per year and an expectation of a further increase in the coming decades due to ageing, the CARE-W project was started to improve the AM process performed at the water utilities. The CARE-W project brought together some of the most competent water system management research groups in Europe (SINTEF, 2008). This included eleven partners from eight countries, that also brought in complementary competence, and utilization of the practical experiences from thirteen end-users.

The objectives of the CARE-W project was to develop and improve tools for assessing the state of pipes or needs for rehabilitation, while also including all aspects of rehabilitation decisions. The final product for the project was a Decision Support System for Rehabilitation, this includes (SINTEF, 2008):

- A control panel of Performance Indicators (PI) for rehabilitation,
- A description of technical and statistical tools assessing and forecasting some of the PIs,
- A procedure to define the best choice for annual rehabilitation programming,
- A procedure to define the best strategy for planning rehabilitation investments (at long term: 10 to 20 years)
- A software, called "prototype" in the following of the proposition, that allows to use the above products with the data existing in the respective water utility.

The CARE-W computer-based system for network rehabilitation planning consists of: "*Software dealing with instruments for estimating the current and future condition of water networks, i.e. performance indicators, prediction of network failures and calculation of water* *supply reliability, and routines for estimating long-term investment needs as well as selection and ranking of rehabilitation projects*” (SINTEF, 2008).

Figure 7 gives and overview of the CARE-W model; the input data, the provided toolkit and possible results.

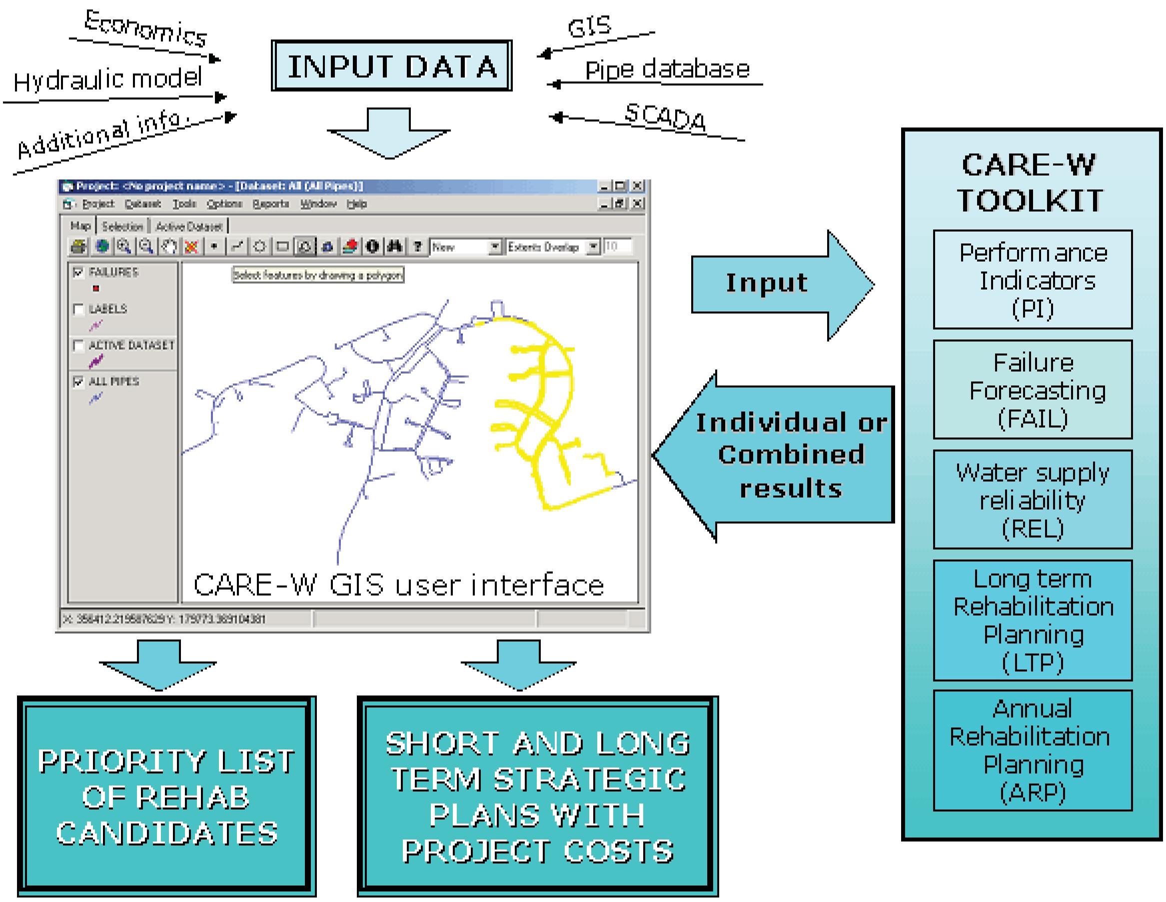


Figure 7 CARE-W overview (SINTEF, 2008)

2.2.2 SIROCO

SIROCO (Système Intégré d’aide au Renouvellement Optimisé des COnduites adapté aux petites et moyennes collectivités distributrices d’eau potable) is a project financed by the French Ministry of Research and aims to deliver integrated decision support system for the rehabilitation of water distribution network, intended for small and medium water distribution companies (Renaud, et al., 2009). It is a result of collaboration between Cemagref and G2C Environment and a consortium of sixteen water companies.

This project is partly based on CARE-W, but where CARE-W was geared more towards larger water companies with sufficient data available, this project is aimed at creating a tool enabling small and medium water utilities to prioritize pipes for rehabilitation (Renaud, et al., 2009). The predicative tools developed in CARE-W assess rate of breaks using statistical models based on knowledge of past failures that have been observed and catalogued. This requires precise and comprehensive databases that include detailed features of the pipes and large amount of historical failure data (Renaud, et al., 2009). The result is that CARE-W is more suited for relatively large water utilities that have these data available. Often small and medium water networks have too few pipes and recorded failure data to be able to use these statistical models (Renaud, et al., 2009). The SIROCO project was started to try to overcome this problem.

Their approach was to create a database that amalgamates data from several companies to overcome the problem of small database size. Since a good knowledge of the network and a structured organisation of information are important in rehabilitation planning, the SIROCO project decided to base it around a geographic information system (GIS) (Renaud, et al., 2009). SIROCO also argued that the complexity of the procedure proposed should be limited, since small and medium sized water utilities often have relatively limited numbers of staff and prefer to use people who are polyvalent instead of specialized.

Based on these three factors, sharing data, make use of a GIS and limiting complexity, the SIROCO project decided to work and focus on the following (Renaud, et al., 2009):

- Definition and collection of data
- Study of the validity of a break prediction model applied to an amalgamated database
- Study of the feasibility of using a model to calculate hydraulic reliability based on data from a GIS.
- Production of a decision support system
- Integration of all tools into the SIROCO software

The study resulted in the data flow and analysis processing shown in figure 8. The conclusion from the project was that they were able to show the feasibility of using an amalgamated database to forecast breaks based on a statistical model and that it is possibly to perform hydraulic reliability calculations with data from a GIS. However, only two of the sixteen water supply companies were able to produce databases needed within the projects time frame (Renaud, et al., 2009). This is therefore possibly a limiting factor for utilizing the results from SIROCO.

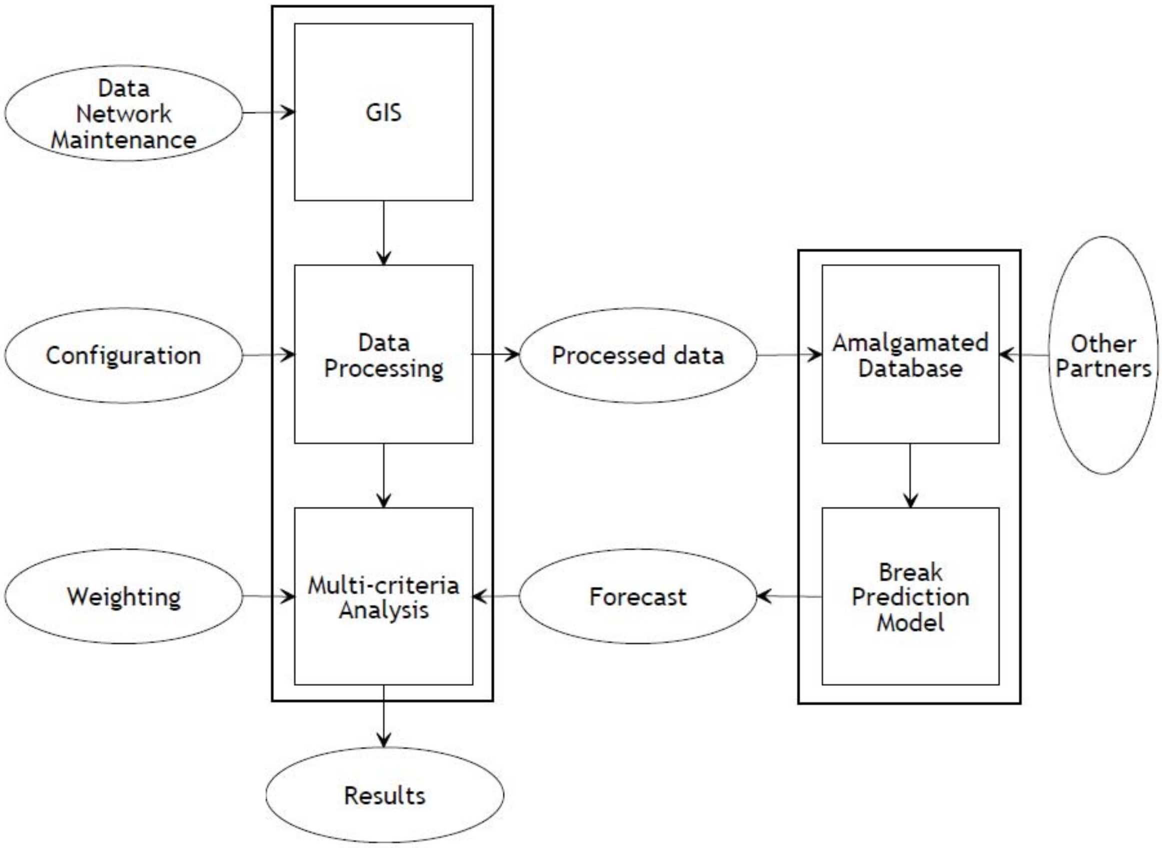


Figure 8 Data flow and processing (Renaud, et al., 2009)

2.2.3 TRUST

TRUST (TRansitions to the Urban Water Services of Tomorrow) is a European project aiming at developing innovations and tools to create a more sustainable water future (TRUST, n.d.). It is a research project funded by the European Union with a time horizon of four years with a start-up in May 2011, and is comprised of thirty partners from eleven different countries. The central objective of TRUST is to *"deliver co-produced knowledge to support Transitions to the Urban Water Services of Tomorrow, enabling communities to achieve a sustainable, low-carbon water future without compromising service quality"* (TRUST, n.d.). This is done with *"research driven innovations in governance, modelling concepts, technologies, decision support tools, and novel approaches to integrated water, energy, and infrastructure asset management"* (TRUST, n.d.).

The TRUST project is a more comprehensive project than the ones previously discussed. It delivers research in various fields and academic disciplines. This project is divided in the following work areas (TRUST, n.d.):

- WA 1: Diagnosis and Vision
- WA 2: Policy, Financing and Society

- WA 3: Analysis Tools
- WA 4: Technologies and Operational options
- WA 5: Future Water Policies and Integrated tools
- WA 6: Implementation and Demonstration
- WA 7: Dissemination and Knowledge Transfer
- WA 8: Management

This report will not be going into details of the different aspects, elements or results for this project, since it is a relatively wide-ranging and broad research project. It is however a very interesting project that will likely yield results that can further benefit the water utilities in their AM planning. Perhaps especially in WA3 where they have a focus on creating tools for metabolism analysis and system performance evaluation of the urban water cycle services, according to state-of-the-art systems analysis approaches (Sægrov, n.d.).

2.2.4 AWARE-P

Another exciting project is the AWARE-P R&D initiative. The objective of AWARE-P is to *"develop and implement in water utilities a structured procedure for infrastructure asset management"* (AWARE-P, 2011). This is both based on previous and new R&D results. This project will provide an open-source, professional-grade computer application, in addition to manuals of best practice and learning material. Previous R&D projects AWARE-P used as stepping stones to develop their product includes CARE-W. Several of the tools/methods presented in AWARE-P are based on results from the CARE-W and CARE-S projects (AWARE-P, 2011).

One of the things that is really interesting about AWARE-P is that they both try to establish and argue for a specific asset management methodology, in addition to develope specific analytical tools. This include certain similar tools as some of the ones developed in CARE-W, but is presented on an open-source web-based platform that makes it easy accessible (baseform.org, n.d.). The AWARE-P software delivers the means to *"visualize, diagnose and evaluate any given water supply, wastewater or stormwater system, through a portfolio of performance, risk and cost models, at both global and detail levels; and, if so desired, to compare a system with any number of planning alternatives or competing projects using standardized methods that facilitate choice and decision-making – both manually and with the assistance of decision-support tools – tested against current or projected scenarios"* (Vitorino, et al., 2012).

2.3 REFERENCE IAM APPROACH TO BE USED IN THE CASE STUDY

The software and tool focus, combined with presenting a complete asset management methodology, gives the AWARE-P project a completeness not many other initiatives can offer. It seems that of today the AWARE-P methodology and analyses tools possibly gives the most comprehensively developed basis for an asset management approach. The fact that AWARE-P tries to incorporate already available research results and approaches, while also developing new solutions or methods, makes it an interesting reference approach for the purpose in this thesis. In the present case-study, AWARE-P will therefore be used as a reference approach in the discussion of how IAM can be incorporated in a small to medium Norwegian water utility.

Consequently, a more detailed and in-depth presentation and study of the AWARE-P methodology and analytical tools will be presented.

3 A COMPREHENSIVE IAM APPROACH – THE CONCEPT OF AWARE-P

Compared to the above initiatives where the main focus to a large extent was improvement of tools and data analysis, AWARE-P is an advocate for a whole new paradigm shift in the approach to asset management. It is argued that since water services are so fundamental to public health and welfare, a sustainable development of communities as well as for protection of the environment, a solid and well-funded approach to the management of these services is strongly needed. They are stressing the implications of the fact that all over the western world we are facing an ever aging water infrastructure with a shift of focus from mainly constructing new water infrastructure to maintaining and managing existing assets.

Alegre, et al. (2012) claims that based on what we know of the present situation, in order to be able to ensure high quality and adequate water supplies in the future, a complete paradigm shift for urban water services asset management is needed. This aims towards a more integrated and efficient way of managing the water services. This will include new use of advanced asset management tools and methodologies. Alegre, et al. (2012) puts forward a list of needs that a sustainable management approach should address:

- 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 of the organisation
- Justifying in a clear and straightforward manner the investment priorities

The AWARE-P R&D project aims to address these needs and produce good and effective support tools to assist the water utilities in their decision making and rehabilitation planning (Alegre, et al., 2012). AWARE-P is an international project with five R&D partners; LNEC - National Civil Engineering Laboratory (Portugal), SINTEF Building and Infrastructure (Norway), IST - Instituto Superior Técnico (Technical University of Lisbon) (Portugal), Addition (Portugal) and Ydreams (Portugal). The vision of the project is to *"provide water and wastewater utilities with the know-how and tools needed for efficient decision-making in the scope of infrastructure asset management of urban water services"* (AWARE-P, 2011).

In short, Alegre, et al. (2012) states that the main objectives of the AWARE-P IAM approach are to assist in answering four essential questions for a water utility:

- Where are we at the present, and what service do we deliver?
- What do we own in terms of infrastructure?
- Where do we want to be in the long term?
- How do we get there?

To be able to answer these questions and assist the water utilities in their asset management planning, AWARE-P introduces both a specific IAM methodology or concept, as well as a set of tools to support in asset management decision making. Probably the most important aspect of the AWARE-P project is the introductions of a specific and well-presented methodology that can better assist the water utilities to understand the necessity of good and reliable AM strategy as well as giving the knowledge on how to best handle AM for their specific system. However, a good choice of tools to assist in AM and also better presenting of the results will be a great help in optimizing the rehabilitation and maintenance of a water infrastructure system.

3.1 THE AWARE-P METHODOLOGY

The AWARE-P methodology incorporates the IAM principles discussed earlier on this report. The cube presented in figure 6 is the backbone of the AWARE-P approach. It advocates that IAM must be addressed at the three different planning decisional levels: strategic, tactical and operational as well as also signifies the need for standardised procedures to be able to asses different intervention alternatives in regards to performance, risk and cost (Alegre, et al., 2012).

AWARE-P looks at IAM as management process built on Plan-Do-Check-Act (PDCA) principles. The four phases in this asset management tactic therefore includes (MindTools, 2013):

- **Plan**: Identifying and analysing the problem
- **Do**: Developing and testing a potential solution
- **Check**: Measuring how effective the test solution was, and analysing whether it could be improved in any way
- **Act**: Implementing the improved solution fully

The PDCA model is a clearly defined, repeatable process that can and should be repeated numerous times to get the best result and to encourage continuous improvement. Figure 9 illustrates the traditional model and the four phases of PDCA

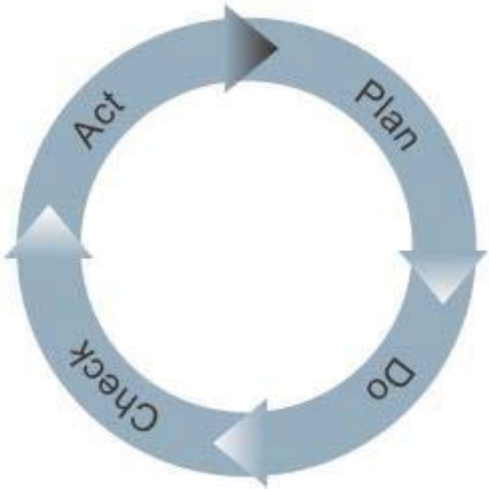


Figure 9 The PDCA Cycle (MindTools, 2013)

The AWARE-P methodology utilizes this well-known project management model and adapts it so it can be used efficiently when managing a water service network. The methodology is proposed as a structured loop consisting of the stages described in figure 10, figure 11 and table 2. This is done for each of the management and planning levels. Figure 10 illustrates the interaction between each planning level (strategic, tactical and operational).

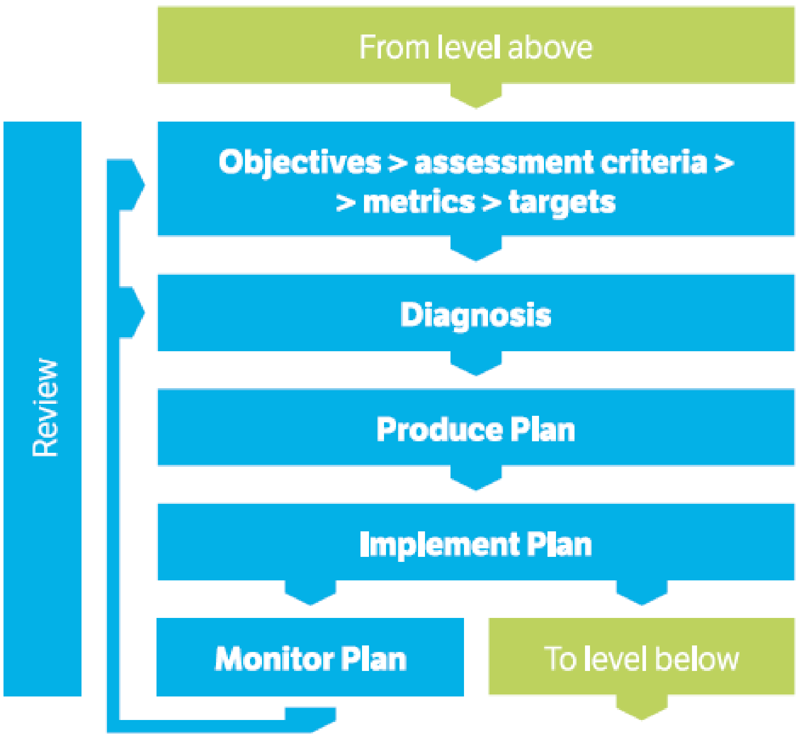


Figure 10 AWARE-P planning process (Vitorino, et al., 2012)

Table 2 AWARE-P planning process, information extracted from (Cardoso, et al., 2012)

The AWARE-P planning process methodology
1. Objectives > assessment criteria > metrics > targets
Definition of objectives, assessment criteria, metrics and targets are crucial stages in order to set up clear directions of action. The objectives are the goals you are aiming to achieve and for each objective it is recommended to specify key assessment criteria. These are points of view that will allow for assessment of the objectives. For each criterion there must be selected performance, risk and cost metrics in order for clear targets to be set as well as for further monitoring of the results. Metrics are specific parameters or functions used to quantitatively or qualitatively assess criteria, while targets are the actual values to be achieved for each metric within a given time frame.
2. Diagnosis
A thorough diagnosis is essential in order to decide where and how to act in an infrastructure system. This is particularly true for the strategic and tactical planning levels. The diagnosis stage assesses the existing system using the established metrics for performance, risk and cost for different scenarios. Scenarios are defined as conditions not controlled by the utility, but which may influence the analysis and should therefore be taken into account. This can include demographic trends, regulatory changes, climate change or other factors. The diagnosis must be done both for present time as well as over the planning horizon. It should be carried out from the whole infrastructure (strategic level), aiming at the identification of global, core problems, to a more detailed analysis (tactical level) of each component.
3. Plan production
Following the diagnosis, alternative solutions can be identified, assessed based on the same metrics, targets and scenarios previously considered, and then compared with each other and with the status quo. These alternative solutions can be strategies, tactics or actions according to the planning level. The solution will be the one that ensures the best trade-offs between performance, risk and cost. The produced plan should be a short and clear document containing the geographical, temporal and thematic scope, as well as objectives and targets for short, medium and long terms. The plan should contain a summary of the diagnosis and of the selected alternative solutions. It should also specify procedures, tasks, responsibilities, scheduling of interventions, financial planning and monitoring and revision frequencies.
4. Plan impementation
The strategic plan implementation is made through the tactical planning development while the tactical implementation is made at the operational level, where the short term actions are planned and implemented.
5. Monitoring and review
The monitoring and review stage is a process to measure compliance with set goals as well as effective alignment and information flow between the different management levels.

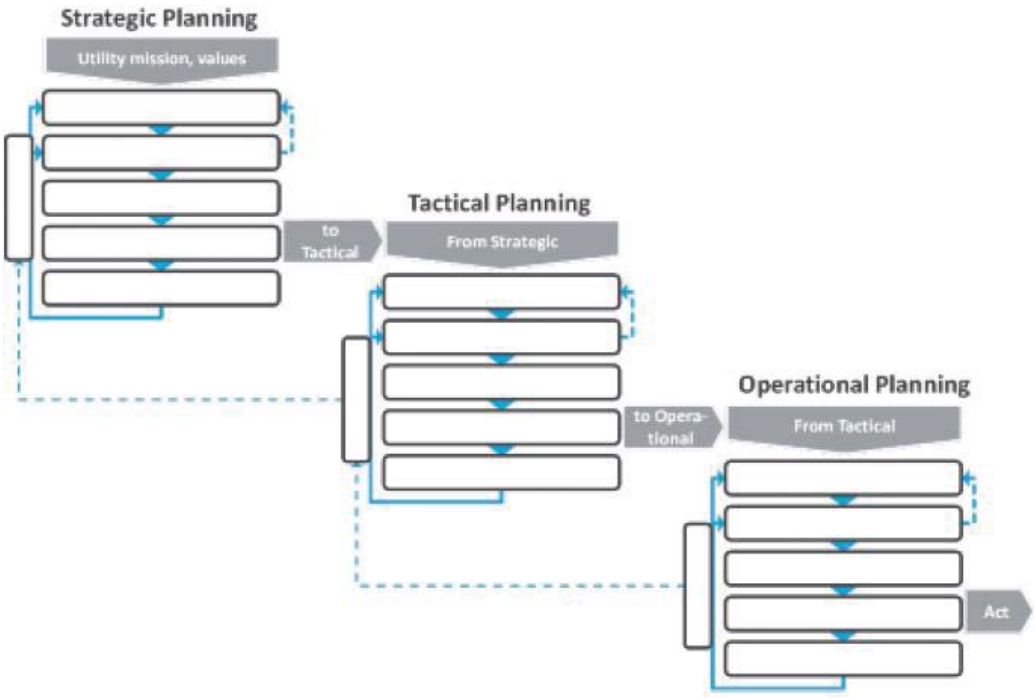


Figure 11 The three planning stages (Alegre et. al., 2012)

3.2 THE AWARE-P IAM PLANNING SOFTWARE TOOLS

The AWARE-P project has also developed a set of software applications, a toolbox, to help facilitate and improve the planning process for water utilities. This toolbox contains a deterioration component for assessing reliability and service life, a hydraulic component for assessing component importance and performance and a decision-support system for assessing different management and investment scenarios (Rokstad, 2012).

What is special about this set of tools is that the AWARE-P project tries to integrate the use and output of the various tools and present them in one web-based application platform (baseform.org, n.d.). This platform permits the user to pool several different sources of data and channel these into the collection of tools in order to evaluate and forecast performance, risk and cost aspects under given management scenarios (Rokstad, 2012). Table 3, taken from Rokstad (2012), lists the tools available in the AWARE-P toolbox as well as a short description of each tool.

Table 3 Tools in the AWARE-P toolbox (Rokstad, 2012)

Baseform Core All the tools in Aware-P rely on the *Baseform Core* platform, a common data manager and user interface platform. The Core handles all data import, and manages all data commonly, which allows for a more seamless interaction between the tools.
PLAN The *PLAN* tool is created to be able to compare different renewal alternatives. The tool consists of three axes; the alternatives axis (for different alternatives), the metrics axis (where different alternatives are compared) and the time axis. In other words, the set of chosen performance metrics can be assessed for each alternative strategy and each future time step, allowing a transparent and informed decision process, by comparing alternatives side by side.
EPANET The *network simulation* tool is based on the EPANET hydraulic model (Rossman, 2000). The tool includes all the functionalities of the standard EPANET model, like dynamic pressure and flow considerations. However, the Aware-P network modeller has expended visualisation capabilities, with the possibility of displaying results in 2D/3D maps as layers on top of third-party maps (such as Google Maps). Modelled parameters from other modules, such as failure rates, can be displayed in the same maps. The tool also allows the export of network data and model results as spread sheet files.
PI The *PI* tool allows the user to define PI's or select PI's from comprehensive lists. *PI* then produces the spread sheets where necessary data must be filled in – what data is necessary, depends on which PI's have been selected. Data can be filled in through the web-browser, or spread sheet files can be downloaded and filled in through spread sheet applications.
PX The *Performance Indices* tool (*PX*) is similar to the *PI* tool, but the *PX* calculates technical performance metrics based on aggregated and/or modelled results (hence can performance indices be modelled for future scenarios). Examples of performance indices are for instance minimum pressures; PX calculates the minimum pressures by the help of the network modeller, compares these to the user's reference values, and returns a graded result to the user in the form of an aggregated result (globally, and for each time step), and a map of the network showing the variations in the results between each asset. The results are graded as good (2-3), fair (1-2), or bad (0-1).
FAIL *FAIL* calculates current or projected failure rates, based on the water mains' characteristics and failure records, either utilising the LEYP model or a Poisson process (depending on the user's choice). In LEYP failures are predicted based a linear extension of the Yule process, with number of previous failures, elapsed time and a set of explanatory covariates as input (Cemagref, 2010, Cemagref.fr, 2011, Le Gat, 2009, Rokstad, 2011a). *FAIL* produces a table of average failure rate estimates for each material and each pipe (which can be displayed in a map) for a given year. The input data for each network main are ID, material, length, installation date, and decommissioning date. For each failure, the data required are failure date, type, duration, and link ID.
LLIFE *LLIFE* is a failure analysis tool, based on the LEYP model. *LLIFE* will go one step further than *FAIL*, by introducing costs of failures to the failure forecasting; if the user provides a certain economic limit, *LLIFE* should then be able to estimate the economic service life of network components (Vitorino, 2012). This tool is still under development, and not yet available
CIMP The *Component Importance* tool (CIMP) uses EPANET to calculate the importance (hydraulic criticality) of each link (pipe, valve or pump) in a water distribution system. This tool requires the input from EPANET and a minimum pressure limit.

UNMET *UNMET* calculates the expected unmet demand from the system, based on the failure rates obtained from FAIL and CIMP. The unmet demand is calculated as the product of the component importance, failure frequency and the average outage time (time between failure and completed repair). The outage time must be provided in the failure logs; otherwise it has to be estimated.
IVI The *Infrastructure Value Index* (IVI) calculates the ratio between the current value of the assets, and the replacement costs, based on material, length, time of installation, expected useful lifespan, construction and replacement costs. When *LLIFE* is finished, it should be possible to use the service life estimates from *LLIFE* as input to *IVI*

The different tools in the AWARE-P toolbox can be used for different maintenance and/or renewal scenarios. This leads to an ability to compare the different alternatives based on a chosen list of metrics for performance, risk and cost. Of course, the results and the credibility of this assessment and comparison are dependent on the availability as well as the quality of the data.

4 PDCA OPERATIONALIZED - OBSERVABLE HALLMARKS

In order to test the application and usefulness in an actual organization, it is necessary to operationalize the AWARE-P methodology. Creation of fairly precise yardsticks is required to evaluate to which extent this methodology actually is applied or not. It will need to be on an intentional and generic level to judge practices that at the outside look quite different due to concepts, wording and sequence, but at a closer look the intentions and actual content might be fairly similar and thus in accordance with the argued reasons for the methodology. Below, such a framework is developed and called the PDCA Hallmarks. This is outlining the characteristics that one should expect to find if such a methodology is applied in practice.

The theory review of the AWARE-P methodology has shown that there are several different aspects or elements to the methodology that is important to thoroughly understand and follow, to get the most out of such an approach to IAM. The AWARE-P methodology is built on the PDCA principles and adapted to be used for a water utility. AWARE-P argues strongly for dividing the planning process into three main phases, all with a distinct set of sub-stages, ref. figure 10 and 11. Within all these consecutive steps, there are certain elements that need to be done or considered. The theory, as reviewed earlier, demonstrated that, according to AWARE-P, including all these elements in the planning process for a water utility would substantially improve the IAM process. This will in turn enable a coherent perspective of the system as a whole and result in a higher chance of reaching the best decisions.

A contrast to this, is what Alegre et al. (2012) calls the traditional IAM approach. This is described as a more assets-by-assets practice with less focus on the integrated approach and a lack of adequate information flow between the different planning levels. Alegre, et al. (2012) consider this approach as having several weaknesses compared to the AWARE-P and the PDCA methodology. It is claimed that the traditional IAM planning will not be able to answer important questions during the planning process and therefore not leading to the best strategies for the water utility or the best intervention solutions for specific problems or challenges.

Introductorily in this report, it was found that for small to medium sized Norwegian water utilities there have, only to a limited extent, been used analytical measures and/or decision support tools in the planning process, such as what is offered within the AWARE-P project. It is therefore reason to believe that the planning process actually done in the small to medium Norwegian water utilities would be closer to what has been called the traditional IAM approach.

Within the documentation provided for the AWARE-P planning process and the studies leading up to it, there is, however, no suitable method of comparing the proposed AWARE-P methodology with what is already done within a water utility that might consider applying the AWARE-P planning process. AWARE-P is describing the various steps in a fairly schematic manner. The more detailed content of each step has to a large extent been inferred from arguments and case studies. To do a comparative study between AWARE-P and actual practice, a more precise instrument or analytical framework is needed.

Such a framework is developed and summarised in the table 4, named the PDCA Hallmarks. The content rests upon detailed studies of AWARE-P documentation and case studies applying AWARE-P, but also on more general PDCA literature, ref. the theory review earlier in the report. The key point in the framework has been to identify, for each step, observable characteristics or indicators that can be judged as a proof of practice being in alignment with requirement. The list of indicators has been named "Observable Hallmarks". When studying an actual utility, these hallmarks are what one should expect to be able to observe if the planning process is in alignment with AWARE-P. Contrary, absence of these hallmarks will be judged as a gap and a potential for improvement. For the purpose of illustration and sharpness, I have in the table included a summary of what Alegre, et al. (2012) finds as typical shortcomings in what has been named traditional IAM planning.

It is, however, not sufficient for such a framework just to list action indicators or hallmarks. All the stages and elements in the AWARE-P methodology should be characterised by its specific purpose for why it is done. A reason why exactly that should be incorporated in the planning process must be substantiated. Therefore, for each main stage a defined purpose is spelled out.

For a water utility aiming to improve its asset management, a shift towards the AWARE-P methodology and asset management approach will most likely be beneficial. There is, however, also important to remember that to some extent the AWARE-P approach is only a hypothesis on how to best manage water infrastructure assets, meaning that it is not unequivocally proved that this is in fact better than other possible approaches. It would also be difficult to do in short term, since the planning horizon for strategic planning is 15-20 years. Nonetheless, since this is a method developed and improved by experts in this field and founded on well-known and tested asset management approaches such as the PDCA methodology, it is reasonably to believe that at least some of the elements presented would be useful for a small to medium Norwegian water utility. It is with this in mind that it will be looked at how AWARE-P could be used and possibly adapted for use in a small to medium Norwegian water utility.

To be able to do this, it might be beneficial to understand where utilities stand today in comparison with the AWARE-P approach. Perhaps there are aspects of the AWARE-P methodology that is already a part of their planning process, or that they have other elements in their planning process that have the same purpose as the elements described in AWARE-P.

By using this framework, it will be possible to understand and analyse how the planning process for a specific water utility is conducted today compared with AWARE-P methodology. Do they already include some of the PDCA hallmarks in their planning process, are they suffering some of the same shortcomings as the traditional IAM planning or do they have other elements to their planning process or other ways of doing it, that deals with the same asset management planning challenges as described in AWARE-P?

4.1 THE PDCA HALLMARKS

In table 4, a systematic evaluation of each key area in asset management planning, level-by-level and step-by-step in order to identify expected findings if applied in practice. For each step the observable hallmark is summarised in a stated purpose. In a separate column traditional planning characteristics are described as a contrast. In this way two extremes on a continous variable are established as navigation points for the actual review of practice. The traditional approach is not broken down further than the different planning levels, since by definition this approach does not contain that level of structured systematics.

The above framework will in turn be applied in the detailed review of practices in the case study. The review will be devided in two parts

a) Review of documentation – the formal story
b) In depth interviewing of key personnel - the story told by key personnel

Table 4 PDCA Hallmarks

THE PDCA HALLMARKS		
Key Areas in asset management planning	**Observable Hallmarks**	**Traditional planning**
Strategic planning		
Set strategic Objectives	- Clear and unmistakable definition of objectives, preferable in accordance with ISO standards - Objectives reflecting long term aims and ambitions, time perspective at least 15-20 years - Clear links to community objectives at higher level such as community strategy and vision/mission - Being conducive to easily follow/link back throughout the planning process on the next levels ***Purpose:*** *Establish a clear direction for all later stages, solid anchored in higher level objectives or policies.*	• Objectives difficult to measure or monitor and difficult to ensure alignment from strategic to tactical and operational levels • Objectives with few if any reference to common accepted standards (ISO/EN) • Loose if any reference to vision/mission level • Lack comprehensive plans. • If strategic plans exist typically
Define Assessment criteria	- Criteria that will allow for good assessment of the objectives - Must be relevant and possible to operationalize in metrics ***Purpose****: Establish references for navigation and choices to ensure one do not deviate from set direction*	

Select strategic Metrics	- Covering all of the key perspectives; performance, risk and cost metrics, either quantitative or qualitative - Metrics suitable for diagnosis, comparing courses of action and later monitoring/review - Relevant, reliable and simple - Preferable metrics from “national regulation authorities” if relevant ***Purpose****: Establish measures for managerial control and feedback*	partial plans in the short run and the links between objectives, criteria, metrics and selected alternatives less than consistent • On strategic level, few if any metrics • Systematic monitoring and review schedules typically non existing
Specify Targets	- The actual proposed value to be achieved for each metric within a specific time frame ***Purpose****: Establish unequivocal ambitions*	

Perform Diagnosis	- Utilize selected metrics to set up a diagnosis in order to compare and select alternative courses of action and identifying potential problems pursuing defined strategic deliveries
	- Should include conditions not controlled by utility that can influence outcome
	- Cover the full time horizon, as the objectives
	- Encompass ability to demonstrate best performance, risk and cost trade-offs
	- Examples of approaches could be
	  ○ Variations of SWOT (Strength, Weaknesses, Opportunities, Threats) analyses
	  ○ Pareto Analysis
	  ○ Trends and scenarios	

	***Purpose**: Establish a sound platform where uncertainties are reduced to a minimum and relevant information needed to select among alternatives is provided.*	
Produce strategic plan	- The plan should be concise and short, but need to include summary of diagnosis plus identification , comparison and selection of alternative solutions ***Purpose**: Establish a precise documentation with self-supporting information suitable to guide subsequent steps*	
Implement strategic plan	- Organize, clarify responsibility and define communication/reporting procedures ***Purpose**: Establish the organizational and human capacities required*	
Monitor/review strategic plan	- Procedures to measure compliance with set goals - Procedures for efficient alignment between different management levels – receive, read, understand and act upon feedback from tactical level ***Purpose**: Establish procedures for required corrective actions*	

Tactical planning		
Set tactical Objectives	- Clear and unmistakable definition of tactical objectives, in accordance with ISO standards - Should reflect medium term aims and ambitions, time perspective 3-5 years - Clear links to strategic plan and selected strategic alternative courses of action **Purpose:** *Establish a clear direction for the tactical planning, solid anchored in the strategies derived from the strategic planning.*	• Asset by assets plans • Inappropriate division into analytical relevant subsystems of infrastructure • Loosely coupled planning between ○ The financial perspective ○ The engineering perspective • More frequent than not it is the financial perspective dominating high level planning and engineering perspective on the operational side: "What can we do with the money we have" • Short time horizon – annual/biannual planning and revisions
Define Assessment criteria	- Criteria that will allow for good assessment of the objectives - Must be relevant and possible to operationalize in metrics ***Purpose****: Establish references for navigation and choices to ensure one do not deviate from set objectives and to compare alternatives.*	
Select tactical Metrics	- Include all three perspectives: ○ performance ○ risk ○ cost - Usable for diagnosis, comparing courses of action and later monitoring/review - Relevant, reliable and simple - For examples of metrics, see appendix E	

	***Purpose**: Establish measures to be able to compare alternatives and select best intervention solutions.*	
Specify tactical Targets	- The actual proposed value to be achieved for each metric within a specific time frame ***Purpose**: Establish unequivocal ambitions*	

Perform Diagnosis	- Utilize selected metrics to set up a diagnosis in order to compare and select alternative courses of action and identifying potential problems pursuing defined deliveries
	- Ability to demonstrate best performance, risk and cost trade-offs – across the various parts of the complete infrastructure
	- Examples of approaches could be
	    ○ Failure analysis
	    ○ Hydraulic modeling
	    ○ Component importance analysis
	
	***Purpose**: Establish a sound platform where uncertainties are reduced to a minimum and relevant information needed to select among alternatives is provided.*	

Produce tactical plan	- The plan should be structured and concise, conducive to guide actions on next level.
	- Required content:
	    ○ Precise documentation of selected analyses with particular emphasis on the systems perspective
	    ○ Identification , comparison and selection of alternative courses of action	

	Purpose*: Establish a precise documentation with self-supporting information suitable to guide subsequent steps*	
Implement tactical plan	- Organize, clarify responsibilities and define communication/reporting procedures ***Purpose****: Establish the organizational and human capacities required*	
Monitor/review tactical plan	- Measure compliance with set goals - Procedures for efficient alignment between different management levels – receive, read, understand and act upon feedback from operational level ***Purpose****: Establish procedures for required corrective actions*	

5 PLANNING IN A WATER UTILITY – AN EVALUATION OF COMPLIANCE WITH THE HALLMARKS

To decide the degree to which the case utility is compliant with the hallmarks two approaches are applied.

- A review of planning documentation. All documents were received from the case utility after a meeting where outline of thesis and need for documentation were presented and discussed.
- An in depth group interview with four key people. The main results from the document review were discussed in the meeting.

5.1 REVIEW OF DOCUMENTATION – THE FORMAL STORY

The water utility in Oppegård prepares a master plan (Hovedplan) and a tactical/rehabilitation plan (Tiltaksplan). The master plan aims to deliver a strategic document describing how to face the challenges for the water distribution service in Oppegård in the future. The focus of the present plan is to secure a stable water supply with satisfactory water quality as well as make sure of an adequate handling of the wastewater that minimize the impact on the population and the environment (Oppegård VAR, 2009). Based on the strategies and assessments done in the master plan, the case utility prepares a tactical plan. The goal of this report is to prioritize the necessary actions needed to be done to comply with the requirements of the master plan.

5.1.1 MAIN OUTLINES OF THE MASTER PLAN

- **Objectives:**
  - Overarching objective:
    - "Stable water supply with an even and satisfactory water supply"
  - Sub-objectives
    - Satisfy the demands in the water supply guidelines, both from the water treatment plant and at each demand point
    - Should not be necessary with any restrictions on water usage within the municipality
    - Minimum water pressure of 30 m
    - Average water leakage should not exceed 30 % of the total demand
    - A minimum renewal rate of 1 % each year
    - The whole of the municipality should have a water reserve to cover a minimum of 24 hours of usage if the water supply from the water source or the water treatment plant should fail

- **Current state for the water supply system:**
    - Grey cast iron pipes are most prone to leakage
    - A need for more water flow meters to be able to detect leakages sooner
    - Building a new elevated reservoir that will lead to an average of 28 hours water consumption
    - Identification of areas with one-sided water supply. Water supply from two independent distribution points is the desired state
    - Identification of supply areas with pressure increase and pressure reduction
    - Identification of supply critical water supply pipes

- **Strategies for the water supply system:**
    - Secure a high level of preparedness in the water supply sector by cooperation and agreements with the surrounding municipalities
    - Working with reducing and detecting water leakages
    - Two-sided water supply for all areas
    - Rehabilitate water supply pipes where it gives the highest cost/benefit-ratio, but also in connection with rehabilitation of wastewater pipes
    - Proactive actions and rehabilitation of the water treatment plant in Oppegård to secure safe drinking water in compliance with the drinking water guidelines

- **Economy and financing:**
    - 8 million NOK for rehabilitation of pipes
    - Funding through the water service charges

5.1.2 MAIN OUTLINES FROM THE TACTICAL PLAN:

- Economical framework:
    - 3 million NOK for two-sided water supply
    - 8 million NOK for rehabilitation of water supply pipes
- New projects:
    - Construct water supply for new residential areas
    - Two-sided water supply
    - Installation of water flow meters and reduction valves
- Rehabilitation:
    - Prioritising of pipes to be rehabilitated
    - Coordination with other projects, especially in conjunction with rehabilitation of wastewater pipes. More often than not it is the wastewater rehabilitation that controls the rehabilitation of water supply pipes.
    - Rehabilitation of specific components in the water supply system, such as pumps, pressure reduction valves and manholes

5.1.3 DISCUSSIONS AND FINDINGS

The analyses of the planning process documentation in the case utility will focus on comparison with the AWARE-P methodology in order to decide level of compliance. It is important to remember what is discussed earlier. AWARE-P is claiming that following a PDCA approach will lead to better IAM. Strictly speaking they are not providing conclusive evidence that the approach in 20-30 years automatically will render a better situation. Along the same lines it should also be remembered that AWARE-P are not arguing that it is not possible to obtain good results through other approaches. However, they are convincingly arguing that one needs to move away from what they have termed the traditional planning approach, ref. PDCA Hallmark table. Therefore, even if findings within the planning documentation for the case utility shows that there are few similarities with PDCA, this might not necessarily mean that the solutions found in the utility are less optimal than if the planning process was more in alignment with the PDCA method. The crucial question is therefore not necessarily if they deviate, but if they deviate in the direction of the "traditional approach".

The main impression after documentation review is that all in all what we find seems to be fairly consistent with what Alegre et. al. (2012) describes as the traditional IAM planning. On the one hand, there are without doubt clear elements in the planning process for the case utility that are consistent with the hallmarks for the AWARE-P methodology. By going through the steps in the PDCA approach it is possible to see several and obvious similarities for the majority of steps, between what is done or included in the planning process for the case utility and what should be included according to AWARE-P. On the other hand, what seems to be lacking is the systematic link between each step, the possibility to easily follow and understand the relations between the different steps in the planning process, and the systematic coherent analysis and arguments for selection of alternatives based on firm knowledge of trade-offs.

In table 5, there has been introduced a grading scale in regards to how close the planning process in the demo case utility is to the PCDA approach introduced in AWARE-P. For each step in the PDCA Hallmarks table there has been done a comparison and then given a grade of compliance with the PDCA Hallmarks. The following four-scale ranking has been introduced:

- Compliance with the PDCA Hallmarks
- Some compliance with the PDCA Hallmarks
- Limited compliance with the PDCA Hallmarks
- No compliance with the PDCA Hallmarks

Table 5 Evaluation of compliance with hallmarks

Key Areas in asset management planning	**Observable Hallmarks**	**Evaluation of the case utility**
1. Strategic planning		
1.1 Set strategic Objectives	- Clear and unmistakable definition of objectives, preferable in accordance with ISO standards - Objectives reflecting long term aims and ambitions, time perspective at least 15-20 years - Clear links to community objectives at higher level such as community strategy and vision/mission - Being conducive to easily follow/link back to throughout the planning process on next levels ***Purpose:*** *Establish a clear direction for all later stages, solid anchored in higher level objectives or policies.*	• A strategic objective in the master plan is found. • Time perspective is in accordance with hallmark. • New objectives/targets are presented throughout the master plan. However, frequently unclear if they are on a strategic or a tactical level and typically with an unclear link to the main strategic objective. • Leaves an impression of less than clear division between distinct planning levels. *Limited compliance with the PDCA hallmarks.*
1.2 Define Assessment criteria	- Criteria that will allow for good assessment of the objectives - Must be relevant and possible to operationalize in metrics ***Purpose****: Establish references for navigation and choices to ensure one do not deviate from set direction*	• No documentation of a selected set of assessment criteria with good and relevant ability to compare or assess strategies. *No compliance with the hallmarks.*

1.3 Select strategic Metrics	- Covering all of the key perspectives; performance, risk and cost metrics, either quantitative or qualitative - Metrics suitable for diagnosis, comparing courses of action and later monitoring/review - Relevant, reliable and simple - Preferable metrics from “national regulation authorities” if relevant ***Purpose**: Establish measures for managerial control and feedback*	• The documentation contains a few selected metrics like; minimum pressure, water leakage, % renewal rate. • Metrics are not presented or discussed as metrics, but primarily implied in objectives/targets. • Since the metrics are inferred from objectives and the objectives suffer from less than clear division of planning levels, it is difficult to assess the relevance and usefulness for the strategic planning level. *Some compliance with the hallmarks.*
1.4 Specify Targets	- The actual proposed value to be achieved for each metric within a specific time frame ***Purpose**: Establish unequivocal ambitions and yardsticks for management control and follow up.*	• As presented under 1.1 we find stated targets, however there are unclear links between the strategic objective and set targets. It can sometimes leave an impression of being somewhat “randomly” chosen. *Limited compliance with the hallmarks.*
1.5 Perform Diagnosis	- Utilize selected metrics to set up a diagnosis in order to compare and select alternatives courses of action and identifying potential problems pursuing defined strategic deliveries	• The documentation does not contain any systematic discussion of strengths and weaknesses, nor any

	- Should include conditions not controlled by utility that can influence outcome
	- Cover the full time horizon, as the objectives
	- Encompass ability to demonstrate best performance, risk and cost trade-offs
	- Examples of approaches could be
	  ○ Variations of SWOT (Strength, Weaknesses, Opportunities, Threats) analyses
	  ○ Pareto Analysis
	  ○ Trends and scenarios
	
	Purpose*: Establish a sound platform where uncertainties are reduced to a minimum and relevant information needed to select among alternatives is provided.*
		clarified alternatives for strategic action routes.
		
		Not in compliance with the hallmarks.

1.6 Produce strategic plan	- The plan should be concise and short, but need to include summary of diagnosis plus identification , comparison and selection of alternative solutions ***Purpose****: Establish a precise documentation with self-supporting information suitable to guide subsequent steps*	• Strategic plan is provided, including a list of chosen strategies. • No clear documentation of path from the main strategic objective to the strategies chosen. • No documentation of why a selected strategy is necessarily the optimal solution within the financial restrictions. *Some compliance with the hallmarks.*

1.7 Implement strategic plan	- Organize, clarify responsibility and define communication/reporting procedures ***Purpose****: Establish the organizational and human capacities required*	• Difficult to judge through received documentation. *Compliance unknown.*
1.8 Monitor/review strategic plan	- Procedures to measure compliance with set goals - Procedures for efficient alignment between different management levels – receive, read, understand and act upon feedback from tactical level ***Purpose****: Establish procedures for required corrective actions*	• Procedures are not documented. • Present plan contains a follow-up and an evaluation of outcomes of previous plans. *Limited compliance with the hallmarks.*
2. Tactical planning		
2.1 Set tactical Objectives	- Clear and unmistakable definition of tactical objectives, in accordance with ISO standards - Should reflect medium term aims and ambitions, time perspective 3-5 years - Clear links to strategic plan and selected strategic alternative courses of action **Purpose:** *Establish a clear direction for the tactical planning, solid anchored in the strategies derived from the strategic planning.*	• Tactical objectives are stated in the documentation. However, the unclear division between planning levels and the reasons for actual selections persists. • Lack of strategic diagnosis seems to lead to deciding the financial restrictions up front and before thoroughly comparing alternatives and intervention actions to get the

		optimal trade-off between performance, cost and risk. *Limited compliance with the hallmarks.*
2.2 Define Assessment criteria	- Criteria that will allow for good assessment of the objectives - Must be relevant and possible to operationalize in metrics ***Purpose****: Establish references for navigation and choices to ensure one do not deviate from set objectives and to compare alternatives.*	• It is defined in the documentation an assessment criteria for prioritising projects, in terms of a claimed cost/benefit analyses to be done. • Operationalization of the cost/benefit criteria is not provided. *Limited compliance with the hallmarks.*

2.3 Select tactical Metrics	- Include all three perspectives:
	  ○ performance
	  ○ risk
	  ○ cost
	- Usable for diagnosis, comparing courses of action and later monitoring/review
	- Relevant, reliable and simple
	- For example of metrics, see appendix E
	
	Purpose*: Establish measures to be able to compare alternatives and select best intervention solutions.*
		• There are metrics, but not for all three perspectives, cost, risk and performance
		• Metrics not accompanied by sufficient description of how to use or operationalize them.
		
		Limited compliance with the hallmarks.

2.4 Specify tactical Targets	- The actual proposed value to be achieved for each metric within a specific time frame	• Ref. comments for above and 1.1, 1.4 and 2.1. *Limited compliance with the hallmarks.*

	Purpose*: Establish unequivocal ambitions and yardsticks for management control and follow up.*	

2.5 Perform Diagnosis	- Utilize selected metrics to set up a diagnosis in order to compare and select alternative courses of action and identifying potential problems pursuing defined deliveries
	- Ability to demonstrate best performance, risk and cost trade-offs – across the various parts of the complete infrastructure
	- Examples of approaches could be
	    ○ Failure analysis
	    ○ Hydraulic modeling
	    ○ Component importance analysis
	
	Purpose*: Establish a sound platform where uncertainties are reduced to a minimum and relevant information needed to select among alternatives is provided.*
		• The documentation does not contain any systematic discussion of strengths and weaknesses, nor any clarified alternatives for routes of action.
		
		Not in compliance with the hallmarks.

2.6 Produce tactical plan	- The plan should be structured and concise, conducive to guide actions on next level. - Required content: ○ Precise documentation of selected analyses with particular emphasis on the systems perspective	• A tactical plan is provided, including a list of prioritised projects. • Arguments for why the different projects have been selected and prioritised is lacking. *Some compliance with the hallmarks.*

	○ Identification , comparison and selection of alternative courses of action ***Purpose****: Establish a precise documentation with self-supporting information suitable to guide subsequent steps*	
2.7 Implement tactical plan	- Organize, clarify responsibilities and define communication/reporting procedures ***Purpose****: Establish the organizational and human capacities required*	• Difficult to judge through received documentation. *Compliance unknown.*
2.8 Monitor/review tactical plan	- Measure compliance with set goals - Procedures for efficient alignment between different management levels – receive, read, understand and act upon feedback from operational level ***Purpose****: Establish procedures for required corrective actions*	• Procedures not documented. • Present plan contains a follow-up and an evaluation of outcomes of previous plans. *Limited compliance with the hallmarks.*

5.2 IN DEPTH INTERVIEW - THE STORY TOLD BY KEY PERSONNEL

The document review concluded that there seemed to be some compliance with the PDCA Hallmarks, but that they are relatively far from incorporating the full methodology as presented in AWARE-P. It is demonstrated that many of the aspects highlighted as important elements in IAM, are indeed also focused on in the case utility. However, the systematic linking between planning stages is not that evident.

The methodology in AWARE-P focuses on setting clear goals for the different planning steps, goals that have clear and understandable assessment criteria that makes it possible to find solutions that satisfies the targets and enables them to compare compliance with the targets for the monitoring and reviewing process. The importance of producing alternative intervention solutions are also stressed, solutions that are based on solid analysis and documentation and containing comparable alternatives to find the best possible intervention solutions. In the documentation from the case utility it is not that easy to see that their planning process is based and focused on these same elements.

An interview with the key personnel working in the case utility is therefore a good way to further understand the asset management approaches, while also getting their opinions and assessments of PDCA and the AWARE-P methodology. The meeting was held on the 19th of April with four key persons including manager and senior engineers[1].

5.2.1 FINDINGS

In general, it was some positivity towards this approach with easy-to-follow planning steps and focus on use of data and different analyses and so on. They believed it could have it merits. However, they did not fully see the practical application of this rigid planning approach for their water utility. Their argument was that there are too many different aspects and things the people working at a medium sized water utility need to deal with on a regular basis. This contributed to making it difficult to allocate resources for fully utilizing the AWARE-P approach and made it difficult to follow and use this planning methodology. They felt they need to always take a practical orientated approach and get an overview of the situation instead of trying to prepare and follow a rigid or too specific methodology and using complex models and analytical tools to perform different analyses.

The following presents what the water utility is doing today, why they have chosen these approaches and what they believe limit the use of the AWARE-P methodology.

[1] The following persons were present: Stig Bell, Sveinung Lindland, Shima Bagherian and Endre Thomas Alexander Hoffeker.

PLANNING PROCESS

The strategic plan, the master plan, follows from what is decided in the municipal plan. The municipal plan highlights the challenges, objectives and goals for the whole of the municipality. This also includes the challenges specifically for the water utility, what they need to focus on and what is demanded from them. These aspects are incorporated in their master plan. The water utility's strategic planning is also done in parallel with more detailed planning, and the results from the detailed planning are used in the strategic planning. This differentiates from the more clearly divided step-by-step methodology presented in AWARE-P. In Oppegård's planning process, they also need to take into account directives issued by the central government. These are guidelines that the water utilities needs to follow and to a large degree controls what they need to do. In addition, input from local government politicians or municipal administration needs to be followed or at least taken into consideration. This might lead to a thinking that if a lot of the outcome is given, why do a time consuming analysis.

When it comes to tactical planning the case utility has their own way of trying to select and prioritize pipe sections that need to be rehabilitated or areas that need new pipes, in order to in the best possible way comply with their objectives and stay within their budget limit. This selection is based on gathering both engineers and operational personnel and have a sort of "brainstorming" meeting. The goal of the group meetings is to jointly come up with good solutions by connecting and using the knowledge from different people working at the utility.

The way this typically is done is by printing out a map of the whole of the network and then discuss which pipes have given them the most problems or caused the most leakage repairs. This will give them an idea of which pipes needs to be rehabilitated. This can be supplemented by for example a hydraulic model that can help identify problem areas or where the capacity might not be adequate in the future.

Their decisions are not to any large degree based on advanced prediction models or failure analysis. Since they are not, to any great extent at least, using models or tools to calculate failure rates or remaining service life, they do not have the same incentive to focus on data collection. This again might lead to problems in the future if there is a desire to start using these different prediction or failure rate analysis or similar calculations.

Another reason the case utility has chosen to use this brainstorming and collaboratively oriented method, is that it is also a good way to motivate and give the people working at the utility a sense of ownership to the solutions selected and rehabilitation plan produced. This way of planning also makes good use of the experiences and "know-how" of all the people working at the utility, not just the engineers and decision makers, while also reducing the need for analyses and reliable data.

A clear negative effect of this practice however, is that they become very dependent on the people working at the utility and their experience. If they lose key personnel, they will lose a lot of the experiences and the "know-how" the water utility has congregated, since this knowledge to a large degree lies only with the people working there. The transfer of knowledge is also somewhat difficult, since new personnel need a lot of time to gather the same experience to be able to contribute in the used decision processes.

This clearly differs from the AWARE-P methodology that stresses the importance of a clear planning process that compares different alternatives that are based on specific, easy to follow assessment criteria and metrics and their compliance with their set targets.

POLITICAL PRESSURE AND EXPECTATIONS

The water utility believes that there are too many external aspects or elements that need to be considered in the running of water utility to be able to use a comprehensive PDCA methodology. One example of an external aspect they need to deal with is the political pressure. Local politicians exert an expectation and demand to "do more", and do something that is easily presentable and visible. This includes for example a desire to increase the rehabilitation and renewal rate. This rehabilitation/renewal rate is in itself a goal that local politicians want the water utility to have, to be able to show the public and voters that this is how many meters of pipes that have been rehabilitated.

The water utility is then trying to show how much they need to be able to do this, and then later the money is divided between different projects. A consequence of this, the water utility say, is that it sometimes leads to selecting a pipe section that is easier to rehabilitate instead of one that might be more beneficial in the long run – since they are measured on meters rehabilitated. This shows that even though they might know a good or optimal intervention solution, that solution is not necessarily the one chosen because of the need to balance towards the political level.

If the water utility has clear and unmistakable analysis or documented reasoning to support and show the effect of their selected intervention solutions or strategies, this will help the water utility to clearly show politicians or other external factors what is needed. The methodology and tools provided by AWARE-P can possibly support that purpose.

CUSTOMER DEMANDS

It is also pointed out that there is a lot to do on a daily basis such as customer management, fixing pipe leakage, informing about new projects and generally responding to customer feedback. This means that to follow and prepare a holistic, structured plan will today demand more resources than they have. Therefore, often the most important immediate problems will be prioritized. Subsequently, this leads to a more reactive asset management approach instead of proactive or predicative. This is also linked with the water utility's desire to have a good and trustworthy reputation. This means for example being able to repair and fix problems that affect the customer quickly. If someone calls and complains about loss of pressure, pipe leakage or other quality issues, they want to be able to handle these issues fast and effective. This is also somewhat related to the political setting, where it is important to show that the water utility has an effective organisation that is able to handle upcoming problems.

Another demanding element for the water utility is the information processes to the customers, for example when starting new projects where they want to invite the persons affected to a meeting both to inform what is going to happen and answer questions they might have. Listening to the input, suggestions or critic from the inhabitants in the municipality is important for the water utility. This is again related to the desire to have a good relation with their customers, and is of course a vital element for water utilities. However, this demands a lot of resources, and with limited budget, the water utility choses to prioritize this aspect.

PERSONNEL

When it comes to the personnel side, the utility also points out other challenges. In addition to the budget limiting the possibility for the water utility to hire more personnel, it is difficult to find competent people to expand the already experienced work force. This is especially true for people needed to perform analyses and support in using methodologies presented in AWARE-P and the like.

COLLABORATION

Another issue highlighted by the water utility, is the problem with a "top-down" management approach. Even if analysts and experts, possibly external consultants, produce a good and reliable master plan or rehabilitation plan, it is not necessarily easy to convince the people that will implement the plans that this is the best way. If they have not been involved in the planning process, they might not believe that this is the best solution and maybe chose to do something different or they might have lower motivation or interest in optimizing the implementation of the plan. The utility therefore stresses the need for involving all the personnel, from operational personnel, engineers and other people in key roles. They feel that the way they handle the planning process and selection of rehabilitation process today sufficiently ensures this aspect, while the methodology presented in AWARE-P does not in a sufficient degree take this into consideration.

5.2.2 SUMMARY - UNDERSTANDING THE NON-COMPLIANCE

The meeting with the case utility made it possible to better understand how a water utility work and how the planning process is actually done. It made it possible to recognize the different aspects and elements they need to consider and what makes it demanding to follow and utilize an advanced, structured and somewhat rigid planning methodology.

From this, there are especially two aspects that have emerged through the process:

A) **We are dealing with two approaches that is based on very different sets of underlying assumptions:**
   There seems to be two different approaches to the strategy planning depending on the orientation or focus of the planning process. One is the more expertise oriented approach that is advocated in AWARE-P, while the other is the more collaborative or politically oriented approach. AWARE-P seems to have great faith in a rational, step-by-step fact-

based working. In the case study, it is found another way of thinking. When they argue how they need to involve the first line operator level and how they have to find workable compromises and balances between strictly professional reasoning and political consideration and necessities, it is examples of a collaborative approach where different roles and experiences meet and shape descisions in a common process.

Table 6 Two approaches based on different underlying assumptions

Assumptions

Management/expertise oriented approach	Collaborative politically oriented approach
- Clear goals – a technical reality should govern goals and selected means	- Mix of professional and politically based goals where it is necessary to balance symbols and realities
- Alternatives emerge through a dedicated and structured analysis and in digging for facts	- Alternatives emerge based on political realities, activities in other related areas and close collaboration with first line operators
- Experts can find the optimal decision alternatives and correct answers based on sophisticated models. At operational level operators will understand and accept expert decisions	- Alternatives and decisions must be anchored and accepted among the first line operators and their experience

B) Asset management advocates meets a repair culture

The nature of water infrastructure asset management has some build in characteristics that tends to produce a certain amount of conservatism and self-fulfilling prophecies. Long timelines; the time span from decision to implication can be decades. When one does not have to face any immediate consequences, any choice will do at the moment and the room for outside considerations tends to be great. In addition, a limited motivation to learn and find better approaches can be an implication. Infrastructure is out of sight and will typically not be challenged by observers and outsiders; nobody actually cares too much until it breaks. This will typically foster a repair culture, not an asset management culture. One of the possible consequences will typically be a reduction of the value of data and analysis, which again leads to the implication that data is not collected and if a need should arise, data will not be available, and you typically will have a vicious circle.

To embed infrastructure assets management one need approaches that in a serious way factor in the underlying assumptions found, and that, based on this, also can divert the vicious circle and create a spiral of gradually building competence and long term awareness.

Within the framework of this thesis, I will prove that the PDCA hallmarks and AWARE-P toolbox can have the potential power to do this, given that some important amendments are implemented in the operational methodology. I will do this both on the strategic and the tactical level, starting with the latter.

I will argue that the tactical level needs to be the crucial point of focus when structured IAM is initiated. As we have found earlier, the strategic and tactical levels are loosely coupled. The implication is that to some extent tactical and operational decisions are at least as much influenced by established work practices and established truths, than by strategic deliberations. The tactical level is concrete, action- and fact-oriented. Introducing new perspectives and visualizing new potential alternatives at this level will have a greater potential power to shape later strategic processes than vice versa.

Thus, in the next chapter a concrete demo case study will be conducted and documented, based on data and reality from the case utility. The purpose here is then to identify operational challenges following from the vicious circle, such as lack of data, but primarily to demonstrate how an increased emphasize on integrated asset management and use of models and tools can have a significant benefit in a water utility and their planning processes. This will include the use of some of the tools in the AWARE-P toolbox. However, this can not be a comprehensive analysis that take into consideration all different aspects, but will focus on demonstrating an example of use and how a method of this sort can be incorporated in the planning process for water infrastructures. Summarized:

- Identify operational challenges in the process of employing the tools from state of the art IAM support tools
- Demonstrate how an increased emphasize on integrated asset management and use of models and tools can have a significant benefit for the demo case utility and their planning process
- Experience the kind of characteristics or qualities that should be present in AM methodology and tools in order to improve the planning process

On the tactical planning level, I will do a kind of test implementation of key tools from the AWARE-P toolbox suitable to amend identified weaknesses. This should not be read as a comprehensive analysis that take into consideration all different aspects, but as a demonstration of use and how a method of this sort can be incorporated in the planning process in the case utility.

On the strategic level, the primary weakness of the case utility as compared to the PDCA hallmarks, has been found in the lack of discussions about alternatives and diagnosis. They have strategic objective and a set of assessment criteria, but both leaves an impression of being set more based on “this is the perspective we use and always have used”, than on an in depth considerations of alternatives. Lack of data and hard facts makes a diagnosis phase and a structured discussion of strength and weaknesses hard. Based on the outcome from the case study on a tactical level, I will demonstrate how this can be fed into the strategic work and stimulate alternative options to be considered without having to disregard the typical political and collaborative approach, which is natural for the case study to use.

6 EMBEDDING AWARE-P IN A TRADITIONAL PLANNING ENVIRONMENT – A LIMITED CASE DEMONSTRATION

Through review of documents and in depth interview with key personnel, a fairly clear picture of the planning process for that water utility has emerged. They have provided a detailed description of how they prioritize and chose projects today, how synergies with other projects are considered as well as how the political aspect affects their planning process. They also stated their opinion about what they perceive as a fairly rigid, step-by-step process and heavily analytical approach of the AWARE-P methodology.

However, even if they at the present do not see an analytical process as the one AWARE-P recommends as the most cost effective or best approach for them, it is perceived as having some definite merits. The showstopper is a combination of the significant amount of work and how to fit the approach into their well-established planning processes of involving staff at all levels, and various political aspects. Not to speak of the prerequisites related to the need for data not available.

Rightly, it is not feasible to complete a comprehensive PDCA planning for the whole of the case utility's water supply network. On the other hand, that does not mean that there is not possible to get any benefits out of an analytical approach within the AWARE-P framework. The aim of this case study is therefore to demonstrate an approach for how to set up the planning process for a specific limited problem and show how the AWARE-P toolbox can be used to produce a reliable intervention solution to best accommodate that problem, within a fairly limited use of resources and based on the minimal data that actually are available.

This case study will include identifying and sorting the data the case utility already have, getting an overview of where there is a lack of data or a lack of reliable data, precisely demonstrate how to use analysis tools to obtain an analytical and data based rehabilitation plan, and try to show how this possibly could be beneficial – what they might expect to get out of it.

In the chapters about AM in general and the AWARE-P methodology in particular, it was always stressed that an integrated asset management approach where you looked at performance, risk and cost was essential to a good result. In this specific case study it will, however, only be focused on one aspect; service interruption risk. For example performance, performance indicators that allows for the quantitative assessment of the efficiency or effectiveness of a system, will not be included. This can, however, be considered later in a planning process where you want to look at all the three elements; performance, risk and cost.

This study will keep the attention on the benefit that one could gain from following the methodology proposed and the potential benefits from the use of more data in heavier analyses, more than on the completeness of the analysis. In short, this study will show an example of a PDCA planning methodology and go into more detail on how to use analytical tools to prepare a good and reliable intervention and rehabilitation solution.

6.1 UTILIZING AWARE-P METHODOLOGY AND TOOLBOX ON THE TACTICAL LEVEL

6.1.2 PRESENTATION OF PROBLEM AND PLANNING METHODOLOGY

The objective or problem in this case is how to maintain high water supply reliability in the water supply system in the case utility. Here, water supply reliability implies the amount of undelivered water in the system, the unmet demand. To have a high water supply reliability in this setting means that you have a low amount of undelivered water, and vice versa. This objective will normally be within the tactical planning horizon and subsequently with a relative short time frame of around 5 years. By following the AWARE-P methodology as close as possible and utilizing the tools provided within the AWARE-P project, this case study will highlight what the case utility or other water utilities in Norway might expect to achieve from this type of planning process, as well as hopefully give a good example of one way of meeting the challenges of using this method.

Table 7 below shows the different steps in the planning process for the specific problem described, while also including a short description of each step. Since this case study only considers one aspect of the whole of the planning process for a water utility and already has a clearly defined objective, most of the work would be with the analytical processes and working with different tools both for the diagnosis part and the creation of an alternative intervention solution based on water supply reliability.

Table 7 The different planning process steps

Steps in the AWARE-P planning process	Descriptions
Objective	Maintain a high hydraulic reliability/water supply reliability for the water supply network
Assessment Criteria	Level of hydraulic reliability/water supply reliability of the network
Metric	Service interruption risk metric: Volume of unmet demand over a period of one year. This is the expected total volume of unmet demand based on the expected number of failures for each pipe, average outage time and the component importance of each pipe.

Target	The target for this specific metric and assessment criteria should be identified both by what is feasible and what is desired for the water utility. The ideal target should have an unmet demand of zero. This target is close to impossible, but can be something to strive for.
Diagnosis	By utilizing the hydraulic model developed for the water supply network in the demo case utility it is possible to perform a diagnosis of the hydraulic characteristics of the system. Thereby identifying the critical areas or pipes in the network. Ideally, this should be performed for a longer time period, looking at demographic trends and thus being able to identify bottlenecks and the component importance for different pipes. In addition, the diagnosis can include the expected failure rates of the pipes, to get an idea of the needed repair rate. This diagnosis will give the foundation for identifying intervention solutions. The diagnosis can also consists of comparing the calculated value of unmet demand at the the case utility network nodes with the target. Where the performance is not acceptable, there we have the problem and there we need to prepare intervention solutions.
Plan production	Following the diagnosis, different alternative solutions should be identified to maximise the hydraulic reliability of the system for the identified critical pipes/areas. There are different ways of doing this. In the case utility today it is used a more “brainstorming” approach where the experience and knowledge of the people at the water utility is used to make an educated guess of prioritized projects. A different tactic would be to utilize some of the tools presented in AWARE-P (FAIL, CIMP and UNMET) to analyse and make a prioritized list of pipes, and then choose to rehabilitate the pipes that would secure the lowest unmet demand. The rehabilitation of pipes can consist of replacing pipes with new pipes made from a new material, to further decrease the failure rate, or it might be found beneficial to increase the diameter of pipes to increase performance and/or hydraulic reliability.

	The following intervention solutions are proposed: A01: Status-quo. Keeping the existing network as is, and only repair after break. A02: The prioritised list of pipes produced by "brainstorming" and educated guess for Oppegård. A03: Using a prioritized list of pipes to be replaced, a list developed by using tools for pipe failure, component importance and consequence analysis. This follows a like-for-like replacement method, meaning that pipes will be replaced with the same diameter pipes.
Plan implementation	The tactical plan chosen (that in a complete analysis is the alternative selected within the proposed list as the one that better balances risk, performance and costs) will then be implemented at the operational level where the process of rehabilitating the chosen pipes are planned and coordinated.
Monitoring and review	Here it is important to measure compliance with the set goals; how good was actually the solutions chosen?

When looking at this table, what is evident is that this case study has some considerable limitations for actual use. For example, when looking at the different alternative solutions it is clear that when only the volume of unmet demand is considered, alternative A03 will necessarily be the best alternative. Therefore, to be able to use this in a practical setting it will need to be included assessment criteria and metrics that take into account performance and cost, e.g. performance indicators or infrastructure value index (IVI). On the other hand, the demonstration of how to use of the PDCA methodology shown in table 7, can be transferrable to a comprehensive tactical planning process.

Moreover, the analysis part in this case study could in itself be useful. Running a thoroughly diagnosis and prioritizing projects based on failure rate, component importance and estimated unmet demand would contribute significantly to reach more sound and reliable decisions. In addition, by working with the analytical tools provided by the AWARE-P project with the data now available for the case utility, it would be possible to show what data might be lacking or what types of data that needs to be integrated with each other to be able to run analysis that are dependent on reliable input data.

6.1.3 STRUCTURING THE ANALYSIS

After the water utility has established the objective, assessment criteria, metric and target, the first real work is to run a diagnosis of the system. To run a thoroughly diagnosis of the network in regards to the hydraulic reliability there are several aspects that need to be included. Generally, it would firstly be beneficial to look at the expected demographic changes for the area. Where are the specific areas that will likely have a population growth? This can be areas with large housing or commercial development and so forth. By using this data, it is possible to establish where there might arise bottlenecks in the system.

For this case study it will be performed a diagnosis based on hydraulic criticality, failure analysis and expected unmet demand. The results from this diagnosis will then be used as a basis to prepare possible intervention solutions. The data needed to perform a diagnosis based on demographic changes, however, is not at this time available and will be omitted from this analysis.

After running a diagnosis, you might not want to only prepare one possible solution, but rather compare several alternatives. If you, for example, have prepared a list of prioritized pipes to be rehabilitated based only on hydraulic reliability and risk, you might want to see how that alternative compares with other alternatives when it comes to different criteria like cost or performance. The following provides an example of different alternative solutions that might be interesting to compare:

A01:

> This alternative is the status-quo, the base case. This is used to compare how a "do nothing" approach will relate to other possible intervention solutions.

A02:

> This alternative is based on the "brainstorming" approach that is used in the case utility. Inclusion of this alternative can have two positive implications. First, it is possible, and maybe interesting, to see how close the prioritized list comes to the one prepared based on analysis tools – how high the difference in unmet demand is. Secondly, if the case study would be expanded to include performance and cost, and do a complete PDCA planning – how would this alternative compare?

A03:

> The analysis part of this case study will use tools available in the AWARE-P toolbox to show how this alternative intervention solution can be prepared based on data provided

by the case utility. It will compile a list of prioritised projects based on a specific risk analysis built on the failure and component importance analysis done in the diagnosis by the use of the tool UNMET in AWARE-P. The risk of service interruption of a specific pipe depends on not only its likelihood of failure, but also the consequence this failure has on the system. This alternative looks at which pipes will cause the highest unmet demand and then rehabilitate accordingly.

The chosen intervention solution is then prepared to be implemented at operational level. Lastly, the continous process of monitoring and reviewing needs to be performed.

6.1.4 RUNNING ANALYSIS IN THE AWARE-P TOOLBOX

When objective, assessment criteria, metrics and targets are specified it is time to run the data analysis. For this specific case study where it is only considered the hydraulic reliability of the system, it is only used some of the tools that are included in the AWARE-P toolbox. This chapter will explain the types of input data and how it is used, and how the diagnosis of the system is performed; which tools are used, how they are used and how they interact with each other.

INPUT DATA:

The data received from the case utility included an export of their Gemini VA database and an Epanet hydraulic model. Data from these two sources was used to perform the hydraulic reliability and risk analysis

GEMINI VA

Gemini VA is a system to manage, control and document water and wastewater infrastructure, developed by Powel (Powel, 2010). This includes GIS-functionality to visualize the network and to be able to run analysis. A complete Gemini VA system will have a correct topological description of the system as well as information about all the components and their characteristics. It is therefore a useful tool for a water utility. Gemini VA has been used in Norway since 1975 and is now used by most Norwegian water utilities (Powel, 2010).

The Gemini VA database from the case utility contains data for all pipes within the municipality's territory. For the water supply system this includes all together data about 9740 pipes with a total length of 238,4 km.

Before being able to use this data for an analysis, some clean up of the data was needed. First, all pipes outside the municipality's maintenance responsibility were removed. The same was done with pipes not any longer in use or registered pipes under construction. After this cleaning, 2365 pipes with a total length of 116,9 km remained.

To perform the types of analyses we want in this case study, we are completely dependent on some key information. The minimum information we need of each pipe is:

- Type of material
- Length of each pipe
- Age of each pipe
- Dimensions

The data from the case utility suffered to some extent both from missing data and some quality errors. This together with the fact that the complete infrastructure is relatively small raises some statistical and methodological issues.

Length and dimensions of pipes were fairly complete and gave few problems. Regarding age of pipes there were required to do some adaptions. The database contains three date variables 1) registered date, 2) change date and 3) year. In order to have a fairly complete set of data, registered date was used when the year the pipe was laid was missing. There are, however, indications that registered dates have less than desired quality, such as an older change date than registration date.

Regarding type of material, 4 percent of total amount of pipes were not registered. There are different approaches how to deal with missing data of this sort depending on what we assume is the main reason for data not being present. In theory there are three possibilities (Howell, 2012):

1. Missing completely at random, meaning that there is no correlation between the missing data and any other variable recorded about the pipe, both what we treat as dependent variable (break) and other properties of pipe – possible grouping variables. We think of it as there is an equal probability for all pipes that type of material is left out.
2. Missing at random. At first sight it looks fairly similar to above. However, the importance here is if we can assume that the missing does not correlate with the dependent variable. The basic question is if pipes with break have a greater or less likelihood to be missing than pipes without breaks.
3. Missing not at random. Some pipes are systematically missing information about material type.

A closer analysis shows that pipes with missing material seems to be systematically shorter and have smaller dimensions than other pipes, leads us to assume that this is not random. In the analysis they are therefore kept, but treated as a separate type called “Unknown”.

90 percent of the infrastructure is made of either SJG (grey cast iron) or SJK (ductile iron). The third main material was polyethylene. The database registered this as seven different groups (PE, PE100, PE32, PE50, PE80, PEH, PEL). To be able to try to have enough failure data for each material, the different polyethylene pipes together with PVC pipes are grouped into one category called “Plastic”. For the last material, MCU (copper), there is only one pipe and is therefore not that interesting.

Based on the amendments discussed, table 8 gives an overview of the pipe structure:

Table 8 Distribution of pipe materials

Material	MCU	Plastic	SJG	SJK	Unknown	Total
Number of pipes	1	115	976	1172	101	2365
% of total	0	5	41	50	4	100
Average length	15	70	45	52	32	49
Total meter	15	8077	44189	61332	3251	116864
Average age	46	35	36	35	33	35
Dimensions:						
- *100 and less*	1	51	121	191	57	421
- *101-150*	0	2	337	597	22	958
- *151-200*	0	41	233	228	11	513
- *above 200*	0	21	285	156	11	473

The Gemini database also includes a "diary" part where all the different events happening in the system should be registered. This includes for example break/leakage, water flow metering, inspection or repair. For this analysis it is only needed the break data and time to repair. The first registered break is from year 2002, and during a ten years period the case utility has registered 87 breaks. This data combined with the previously discussed data from Gemini VA, enables us to do a failure analysis.

However, there are some uncertainties in relation to these failure data. Firstly, 87 registered breaks is probably not an adequate number of failure events to have a good enough statistically significance. This might implicate that the results of a failure analysis is not entirely trustworthy. Secondly, for the year 2002 there is only registered one break, while for 2003, 2004 and 2005 there are no breaks registered. 2006 has two registered breaks. It is only after 2007 there seems to be an organized recording of breaks, with 13 breaks in 2007 and in the following years between 10 and 20 breaks each year. This leads us to believe that even though the first registered break was in 2002, it is only after 2006 that there was a focus on actually registering breaks in the Gemini VA database. However, for this study all the break data available was used, with the assumption that it is correct.

The break data has the following distribution based on pipe material:

Table 9 Break data distribution

Material	MCU	Plastic	SJG	SJK	Unknown	Total
Number of failures	0	0	75	11	1	87

This table shows that for both material MCU and plastic there is no recorded failures. For MCU this is not that important, since there is only one pipe made from that material. For plastic on the other hand, it could be interesting to calculate a failure rate to be able to predict further failures. With the data available, this is however not possible.

A more in-depth look at the failure data, e.g. why there are few registered breaks and how that lack of data might be accommodated, will be done in chapter 7. For this specific case study however it will only be used the failure data that are available.

EPANET

Epanet is a "*software that models the hydraulic and water quality behaviour of water distribution piping systems*" (US EPA, n.d.). It is a public domain software that can be freely copied and distributed and is developed by the United States Environmental Protection Agency. This software makes it possible to create a network model consisting of pipes, nodes, pumps, valves, storage tanks and reservoirs. The Epanet model is able to track (US EPA, n.d.):

- the flow of water in each pipe
- the pressure at each node
- the height of the water in each tank
- the type of chemical concentration throughout the network during a simulation period
- water age
- source
- tracing

The case utilty has provided their Epanet model that enables us to run hydraulic reliability and risk analysis. The Epanet model in the utility is continually improved. For example, just after the analysis in this case study was performed, the case utility had already developed an updated Epanet model. This model has a few more pipes included, in addition to some other small improvements. The version used in this analysis contains 419 pipes with a total length of 91 km. These pipes are the most important pipe sections in the network, the main distribution lines. This does, for example, not include house connections or other private pipes.

When using a network model it is important to consider the limitations and the possible inaccuracies of the model. This model has, for example, a single demand pattern. With only one demand pattern, it might be a little bit too optimistic to expect great accuracy for the flow values. Additionally, this model has 16 PRV's (pressure reduction valves), which is a fairly high number, and this further increase the possible inaccuracies of the flow values and makes it difficult to completely trust the predicted flow.

One other noticeable factor in this model is that the night consumption is relatively high. This might suggest a high amount of leakage or might be enhanced by the buffering of the elevated basin in the network. Either way, the accuracy of the model is very dependent on the specified demand pattern, which, as said earlier, might not be that precise considering the complexity of the network.

NETWORK

The first step when doing an analysis in the AWARE-P toolbox is to import the network model. This is an Epanet .INP export file. For this case study the Epanet model is provided by the case utility and is used as a basis for the rest of this analysis. The model is relatively complete, meaning that it has all the important pipes included. As said earlier, the NETWORK tool is a full Java re-write and implementation of the Epanet standard (Vitorino, et al., 2012). This also means that it is possible to change basic simulation setting such as duration, hydraulic time step and start time. The Epanet model provided from the case utility has for example included the consumption variations over a 24-hour period, and therefore duration of the simulation is set to 24 hours.

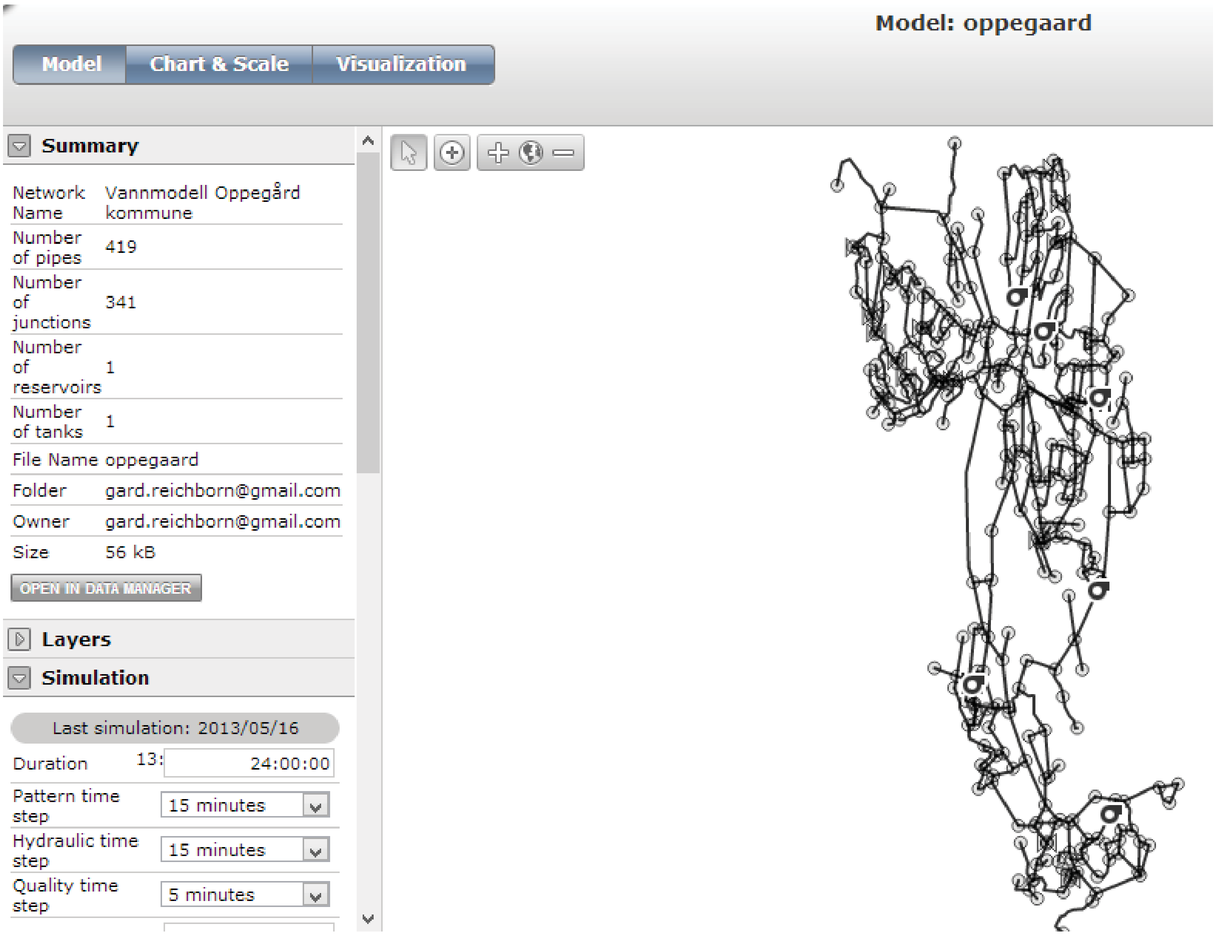


Figure 12 Hydraulic model of Oppegård

CIMP

The CIMP, or component importance, tool calculates a component importance metric for each individual pipe in the network (Vitorino, et al., 2012). This is calculated by comparing the total demand that the network is hydraulically able to satisfy when a specific pipe is out of service, with the total demand the fully operational network is capable of supplying. This calculation is computed over the whole simulation period that is defined in the network model that is used (Vitorino, et al., 2012). The following formula is used:

$$CI = \frac{Q_{tot} - Q_{s_i}}{Q_{tot}}$$

$$where;$$

$$CI = component\ importance$$

$$Q_{tot} = average\ network\ demand, in\ LPS$$

$$Q_{s_i} = supplied\ demand\ when\ pipe\ i\ is\ out\ of\ order, in\ LPS$$

The component importance value given to each pipe is a number between zero and one. Zero means that if that pipe fails, the network demand is still satisfied. In contrast, one means that when that pipe fails, no demand is satisfied across the entire network and over the whole simulation period. This tool is also able to give the average flow that is supplied when the pipe is out of order.

The result from this analysis is a list of pipes sorted after their component importance. With this result, it is possible to get an understanding of which pipes it is necessary to give extra consideration during a rehabilitation planning process. The results from this analysis are presented in figure 13. CIMP also gives the opportunity to export the entire list of files to an excel file for easier data management.

Average network demand 187.51 LPS RE-CALCULATE

Pipe ID	Actual consumption (LPS)	Importance
33	15.9	91.51%
133	17.8	90.49%
23967	100.1	46.62%
21769	104.9	44.04%
21771	105.0	44.00%
21773	106.2	43.38%
19864	121.2	35.37%
24256	127.9	31.78%
28412	128.5	31.46%
25483	128.6	31.40%
127	128.7	31.34%
24927	167.9	10.46%
145	174.1	7.13%
144	174.1	7.13%
23982	175.8	6.25%
23979	176.1	6.09%
20782	176.3	5.99%
23915	176.4	5.90%
24970	176.5	5.87%
24969	176.6	5.81%
25051	176.7	5.78%
20752	181.0	3.48%

Figure 13 CIMP analysis results

When an Epanet model is available for the water network in question, to run a CIMP analysis is relatively easy and the results are clear and easy to understand. However, always when running an analysis of this sort it is important to understand the hydraulic model to fully understand the results.

When looking at the Epanet model we see that the two most important pipes, ID #33 and #133, are connected to the only reservoir in Oppegård. If these two pipes are out of order, almost no water is supplied from the reservoir to the network. Further examination of the model by using source tracing in Epanet shows that the only elevated basin in the network can supply merely about half the network, see figure 14. It also shows that this supply only will last for approximately four hours. Since the one reservoir is the only source of water for the system, and there is a lack of satisfactory temporary back-up solutions, it is naturally to assume that pipes close to the reservoir will have a high component importance value. This is also evident in the component importance list where we see that the six most important pipes are all closely connected to the reservoir.

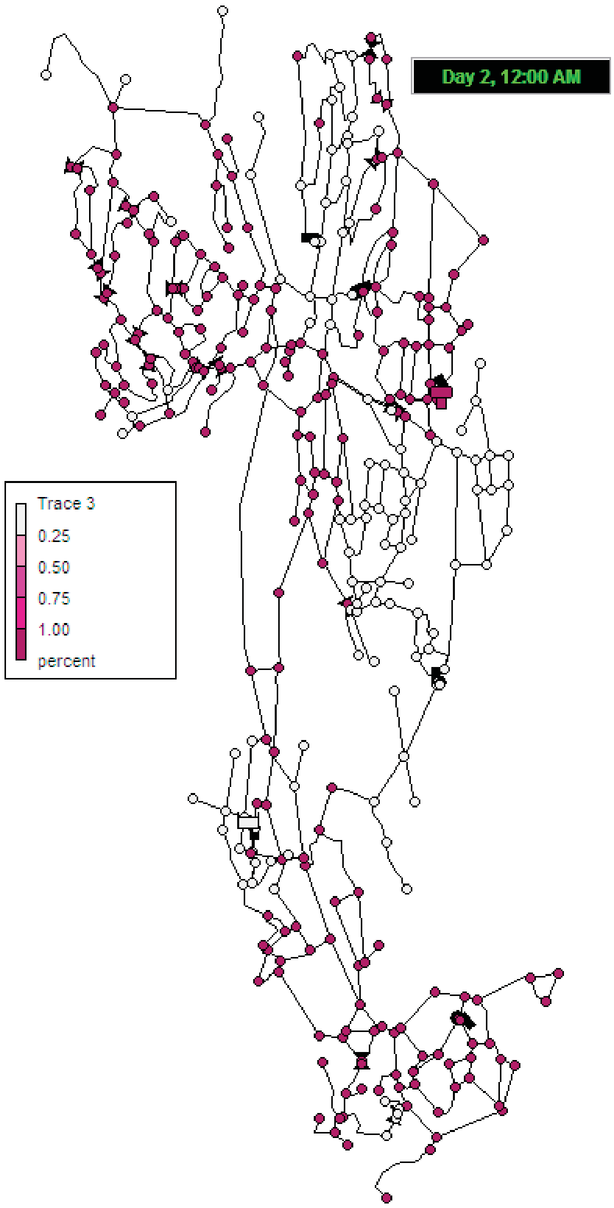


Figure 14 Source tracing in Epanet from elevated basin

Further down the list, there are pipes that supply areas with limited or no two-sided water supply. For example, pipe with ID# 19864 is the only main supply for a relatively large area at the bottom of the system. This is the reason why it has a component importance as high as 35%.

Running a hydraulic criticality analysis as the one done with CIMP will help the analyst to better understand the system and thereby make more qualified suggestions on how to improve the network. In addition, with the results from CIMP together with a failure analysis, it is possible to predict an expected future unmet demand that is able to tell the analyst something about vulnerability and risk.

FAIL

Another useful tool in the AWARE-P toolbox is the failure analysis tool, FAIL. This tool calculates the predicted probability of failure as well as the number of future failure for each pipe based on the historical break data. The two alternative stochastic processes offered for calculating failure predictions are the Poisson process and the Linear Extended Yule Process (LEYP) (Vitorino, et al., 2012).

The LEYP process is the most sophisticated model. It calculates failure rates/probabilities depending on the age of the pipe, the number of past events and a vector of covariates. The covariates used in the LEYP process and in FAIL are the pipe diameter and the logarithm of pipe length. In addition, all the data is divided into the material of each pipe (Vitorino, et al., 2012). This method attempts to find the weights of these variables in the overall prediction, given the failure data made available, creating a mathematical model that then can estimate failure ratio and probability over time for any given pipe.

The LEYP process requires a relative significant amount of failure data to calibrate the model. In this case study the 87 recorded failures are not enough to run this process. Therefore, a Poisson process is needed. This is a simpler counting process that is able to give results even with a smaller dataset. The following will give a brief explanation of the Poisson process based on information provided by Vitorino, et al. (2012).

Notation:

$$\{N(t), t \in \mathbb{R}^+\}\ is\ a\ counting\ process\ constituted\ of\ number\ of\ fails\ during\ time\ periode\ t$$

$$N(t)\ is\ the\ number\ of\ failures\ in\ the\ time\ interval\ [0, t]$$

$$N(t) - N(s)\ is\ the\ number\ of\ failures\ during\ [s, t]$$

$$E[N(t) - N(s)]\ is\ the\ expected\ number\ of\ failures\ during\ [s, t]$$

$$P\{N(t) - N(s) = n\}\ is\ the\ probability\ to\ fail\ n\ times\ during\ [s, t]$$

$$L(\theta|)\ is\ the\ likelihood\ function\ of\ the\ process$$

In the Poisson process the events occur independently at a constant rate γ and the number of events follows a Poisson distribution, $N(t) \sim Poisson(\gamma t)$. In FAIL it is assumed that the rate of the counting process is proportional to the length of each pipe. The number of failures in pipe *i* follows $\{N(t), t \in \mathbb{R}^+\}$ with rate $\gamma_i = \lambda l_i$. Here l_i is the length of the pipes and λ is the failure rate (number of failures/year/km).

λ is estimated by the maximum likelihood method:

$$\hat{\lambda} = argmax_{\lambda \in \mathbb{R}^+} L(\lambda | n, t, l) = \frac{\sum_{i=1}^{m} n_i}{\sum_{i=1}^{m} l_i t_i} \qquad (1)$$

$$where:$$

$$m \text{ is the number of pipes}$$

$$n = [n_1 \dots n_m] \;\; n_i \text{ is the number of recorded failures of pipe } i$$

$$l = [l_1 \dots l_m] \;\; l_i \text{is the length of pipe } i$$

$$t = [t_1 \dots t_m] \text{ and } t_i \text{ is the observation period of pipe } i$$

If λ is estimated by using the entire data set, the estimated failure rate will be the same for all pipes. However, it is possible to separate the data set based on pipe characteristics, e.g. material and diameter, and thus creating different categories that each have their own failure rate. Consequently, the failure rate λ_k can be estimated for each category C_k using equation 1, but only for pipes in C_k.

The probability of a pipe in C_k to fail *n* times during time interval [t, t + s] is given by:

$$P\{N(t+s) - N(t) = n\} = \frac{e^{\lambda_k l_i s}(\lambda_k l_i s)^n}{n!}$$

and the predicted number of failures in pipe i is based on the expected value of the Poisson:

$$E[N(t+s) - N(t)] = \lambda_k l_i s$$

In the Poisson implementation in FAIL, the data set is divided based on the pipe material and consequently creating pipe material categories. This means that you get a failure rate for each material. The predicted number of failures in each pipe is found by using the expected value of the Poisson distribution, while the failure probabilities are found using the Poisson probability function. As with CIMP, it possible to export the failure data to an excel file.

Running this analysis with the data set from Oppegård yields the results presented in figure 15:

Summary

File name	Failure Analysis Clean Data
Folder	Work Orders
Owner	gard.reichborn@gmail.com
Size	2365 rows
Work Order Pipes	Work Order Pipes Clean Data
Work Order Failures	Work Order Failures

OPEN IN DATA MANAGER

Model info

Model	OK
Pipes	459
Junctions	388
Simulation	24:00:00 hours
Hydraulic step	00:15:00
Units	SI
Headloss formula	DW

CHANGE OPEN MODEL

Poisson LEYP

Material	Prob. Fail. 1 year, 1 Km	Fails. per year	Fails./km per year
MCU	0.00%	0.00	0.00
Unknown	4.70%	0.16	0.05
Plastic	0.00%	0.00	0.00
SJG	15.22%	7.29	0.17
SJK	1.89%	1.17	0.02

Pipe ID	Failure Rate	Failure Probability
25089	0.0624	6.1%
23791	0.0580	5.6%
25088	0.0477	4.7%
23979	0.0463	4.5%
20782	0.0393	3.9%
23915	0.0382	3.7%
23790	0.0379	3.7%
24927	0.0374	3.7%
50108	0.0332	3.3%
23867	0.0324	3.2%
220	0.0320	3.1%
23748	0.0301	3.0%
23254	0.0266	2.6%
25068	0.0259	2.6%
36202	0.0245	2.4%
22110	0.0228	2.3%

Figure 15 FAIL analysis results

This shows that grey cast iron has by far the highest failure rate. This is concurrent with what is presented in the case utility's own rehabilitation plan where they in general want to prioritize the rehabilitation of grey cast iron pipes. We also see that for plastic, the failure rate is zero due to the lack of registered break. This is of course a limitation of the analysis and makes it impossible to predict the failure of these types of pipes.

It could also be beneficial to check if the failure rates from this type of analysis are in the same range as for other water supply networks. This can both contribute to check if there might be something wrong with the analysis, perhaps an error with the sorting of data, or to try to find out if there are some special circumstances for the network that might explain a discrepancy.

Utah State University has performed a comprehensive study of the water main break rates in the USA and Canada (Folkman, 2012). The purpose of this study was to offer data and analysis that utility managers can apply to the situation of their own operations. One of the key focuses in this study was the break rates of pipes. It used experiences and data from 188 utilities in the USA and Canada to compile aggregated data on pipe material break rates and analysis of age and corrosion in failure modes.

Table 10 Failure rates in the USA and Canada, sorted by pipe material ((Folkman, 2012)

Pipe material	Failure rate [fails/km/year]
Grey cast iron	0,152
Ductile iron	0,030
PVC	0,016

This shows that the case utility is approximately in the same range, possibly a little higher. A comparison with this sort of study might lead to a possibility to use data from other water utilities to supplement for the lack of data for the water network analysed.

UNMET

The two previous tools in itself can be suitable to provide a pointer for a water utility when preparing a rehabilitation plan. However, by combining the results from these two analysis, it is possible to get an even better idea of which pipes has the highest risk of limiting the water supply. The AWARE-P project has developed a tool that is able to calculate this. The UNMET model calculates a service interruption risk metric (Vitorino, et al., 2012). This tool uses the results from CIMP and FAIL to project the expected amount of demand that are not met. The way the tool calculates this is that for each pipe the value of expected unmet demand in case of outage is multiplied by the pipes expected number of failures in 1 year, and by the average outage time (Vitorino, et al., 2012). The result of an analysis of this sort is the expected value of the total volume of unmet demand in the network caused by the individual outage of each pipe. This provides a direct measure of expected loss of service or even loss of revenue if multiplied by the unit revenue.

When using the tool you chose the appropriate failure analysis and component importance table. The result is a total expected unmet demand as well as a list of pipes prioritized by expected unmet demand. The results of this analysis are shown in figure 16. This figure shows the total expected unmet demand per year as well as four pipes with the highest unmet demand per year. To get a complete list of the expected unmet demand, this tool gives the possibility of exporting the whole list of pipes with the corresponding unmet demand to excel.

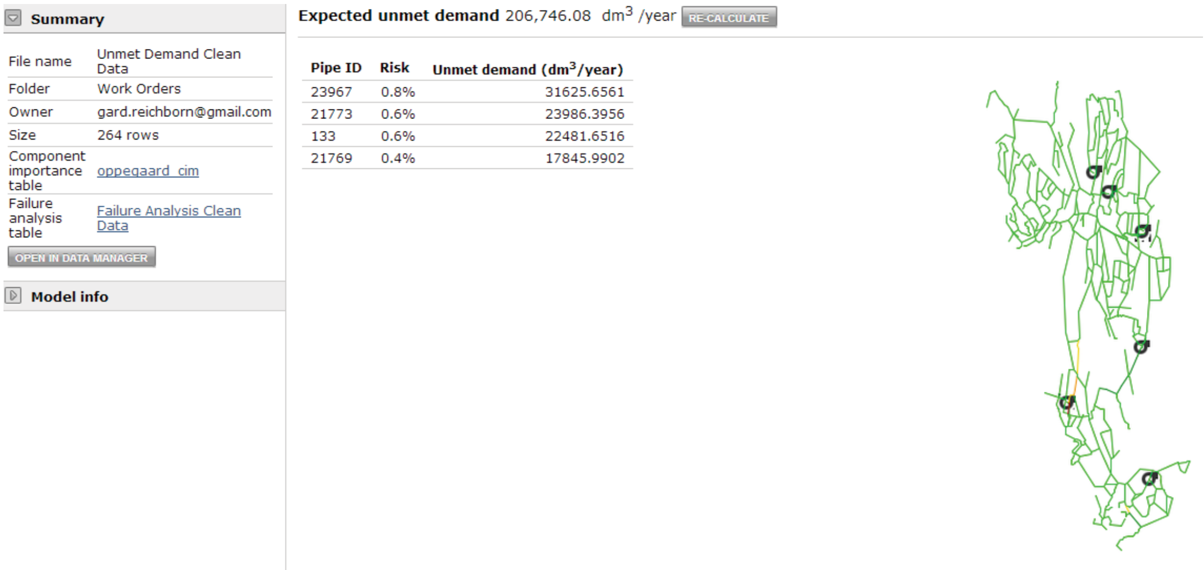


Figure 16 Results from UNMET analysis

The limitation or problem with this analysis for this network, is the discrepancy between the data set from Gemini VA and Epanet, that not all the pipe ID# matches. To be able to properly utilize the UNMET tool, this needs to be remedied. One of the problems is that each pipe, from manhole to manhole, in Gemini VA is often divided into sections with different ID#, while in Epanet this is one pipe with one specific ID#. The reason for dividing it in sections in Gemini VA can be because the different sections have some different pipe properties or different construction year, either way this makes the analysis difficult. The resolution of this sort of problems will demand some work from the water utilities side, and must therefore be justified by the value of this type of analysis.

6.1.5 PREPARING INTERVENTION ALTERNATIVES

There are different ways of preparing rehabilitation plans and prioritize what needs to be done. One way is what they do in the case utility today, where they have this "brainstorming" process where they try to combine the experiences and knowledge of the different people working in the water utility to come up with good solutions. Another way is to rely more on registered data and analysis tools. This chapter will show how some of the tools provided in the AWARE-P toolbox can be used to make a prioritized rehabilitation plan based on hydraulic reliability and risk.

This will focus on the use of the three tools described earlier; CIMP, FAIL and UNMET. After importing the data needed for FAIL and CIMP, the results from these tools can be used to make the prioritized list in UNMET, figure 16. If you only choose based on risk, you can use the list of pipes with the greatest impact on total expected unmet demand to select the pipes to be rehabilitated, and see how this affect the total unmet demand. In addition, you might want to look at the hydraulic criticality index or component importance to reduce the effect of a failure. The case utility in their rehabilitation plan for example has expressed an interest in securing a two-ways water supply for all areas for just that reason. The following will explore these two options.

1. SELECTING REHABILITATION OF THE EIGHT MOST IMPORTANT PIPES IN UNMET AND THEN RUNNING THE UNMET ANALYSIS AGAIN TO SEE HOW THIS WILL AFFECT THE TOTAL UNMET DEMAND.

Table 11 Top 8 most important pipes in UNMET

Pipe ID	Risk	Unmet demand [dm^3/year]	Length [m]
23967	0,007743482	31625,65613	101,46
21773	0,005882101	23986,39562	82,70
133	0,005533825	22481,65163	37,16
21769	0,004384281	17845,99021	60,61
21771	0,003994232	16251,12235	55,24
24927	0,003844186	15862,82835	226,81
24256	0,003747180	15266,84761	71,86
23979	0,002753294	11411,19194	280,25
			Total length: 916 m

Table 11 shows the eight pipes causing the highest expected unmet demand. Rehabilitation of these pipes gives the following expected UNMET demand and the new pipe priorities:

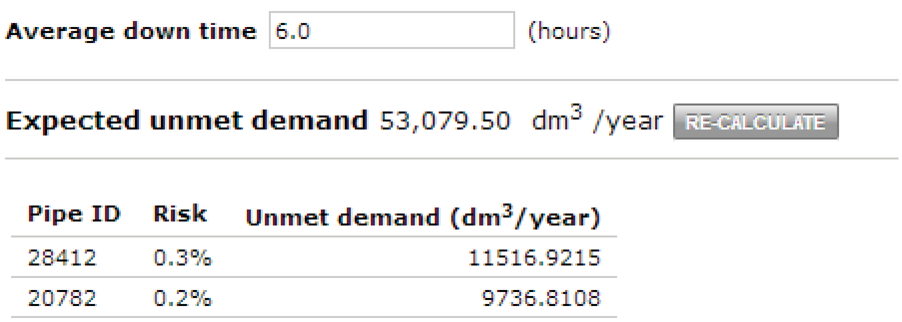


Figure 17 New total expected unmet demand

We see that by rehabilitating just the eight most important pipes with a total length of 916 m, reduce the total expected unmet demand with more than 74%. The result of rehabilitating individual pipes can be visualized in a chart that shows the effect of rehabilitating one to eight of the most important pipes in UNMET, figure 18.

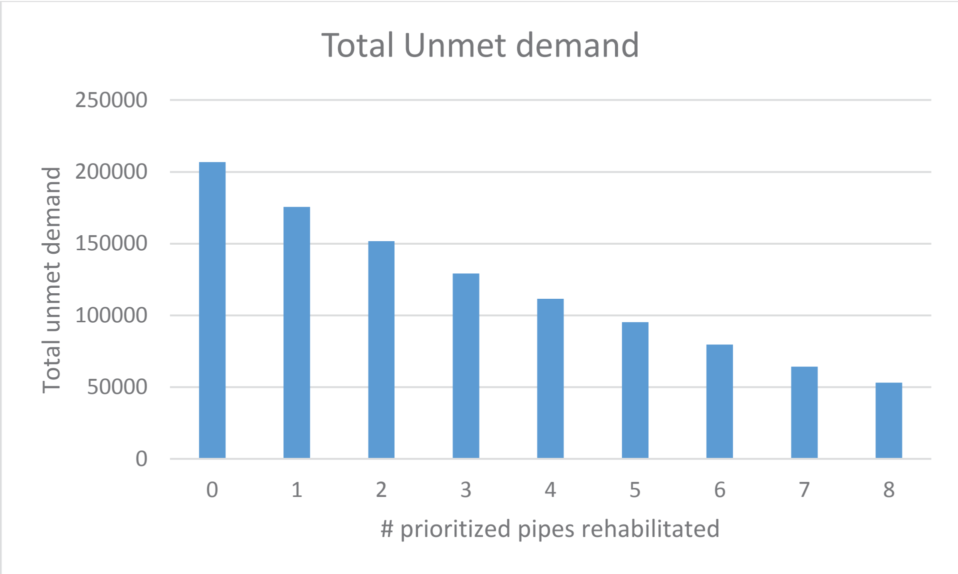


Figure 18 total unmet demand vs. number of pipes rehabilitated.

We see that unmet demand is drastically reduced, especially for the first pipes. If desired, this can be expanded to show the effect of rehabilitating even more pipes. By using this type of chart it is easy to select the pipes that need to be rehabilitated to meet the specific assessment criteria and metric set for risk/unmet demand. Since the length of the pipes is available, it is also possible to show a simple estimation of cost relevant to how many pipes are rehabilitated or the value of unmet demand, see figure 19 and 20. The cost per meter of pipe is here set to NOK 1300, based on the basic data for strategy calculations for the BIT project in Oslo VAV (Hathi, 2012). It is assumed that this estimated cost for Oslo is relatively close to what can be expected in Oppegård.

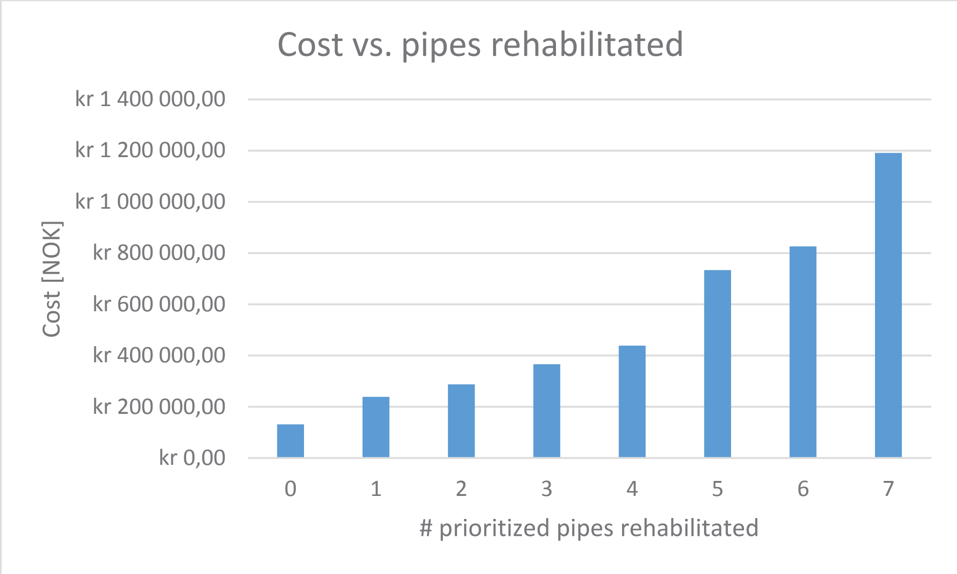


Figure 19 Cost vs. pipes rehabilitated

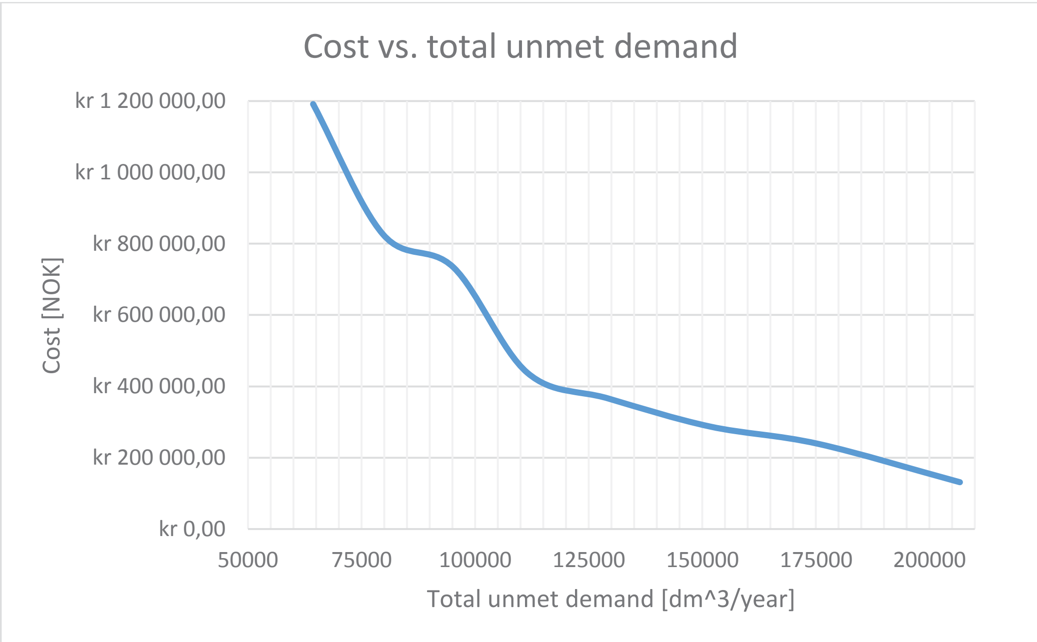


Figure 20 Cost vs. total unmet demand

These charts enable the analyst to easily visualize the effects investment cost will have on the unmet demand and estimate the cost for reaching the metric value for these assessment criteria. This can for example be beneficial when presenting the results to politicians or others who is responsible for the budget of the water utility; "*if we get this much more money, we are able to reduce the risk of service interruption by this much*".

2. CHECKING WHAT ADDING AN EXTRA PIPE TO AN AREA TO SECURE TWO-SIDED WATER SUPPLY WILL AFFECT THE TOTAL UNMET DEMAND.

The case utility states the importance of a two-sided water supply to all areas. Looking at the Epanet, we see that pipe with ID# 19864 supply water to an area with only 1-sided water supply, see figure 21. This pipe is also relatively high up in the component importance list, making that area a good choice for upgrading to a two-sided water supply. Adding an extra pipe gives the results presented in figure 22.

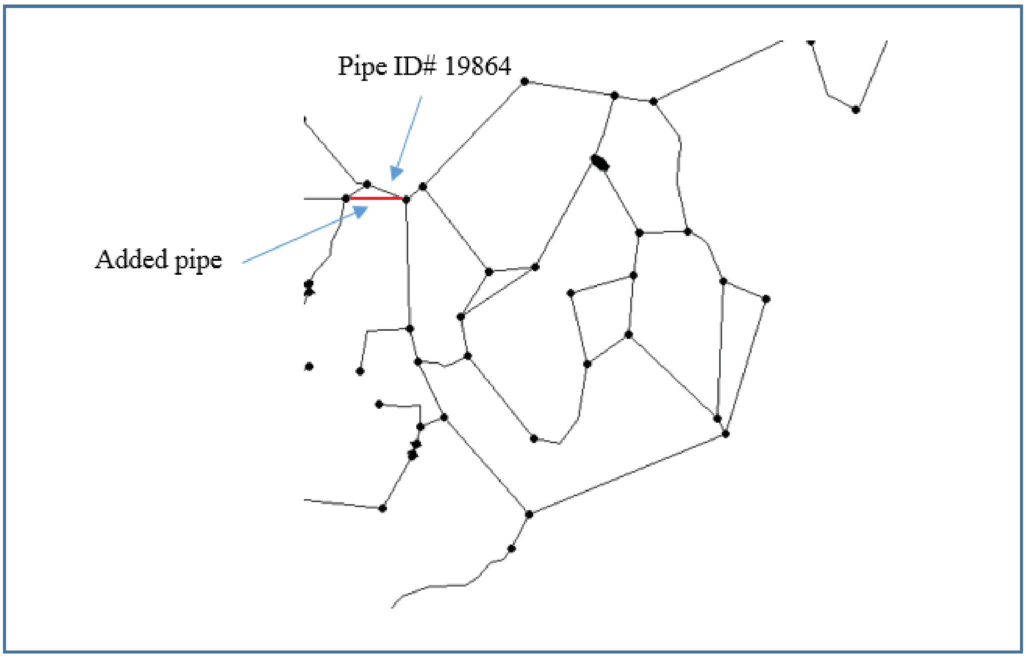


Figure 21 Added pipe

Average down time 6.0 (hours)

Expected unmet demand 130,613.35 dm^3 /year RE-CALCULATE

Pipe ID	Risk	Unmet demand (dm^3/year)
133	1.0%	38687.2069
23967	0.5%	18442.2873
21773	0.3%	13044.2754

Figure 22 Expected unmet demand with added pipe

One of the goals in the rehabilitation plan for the case utility was to ensure more reliable water supply by two-sided water supply. However, by using CIMP, FAIL and UNMET it is possible to see the actual effect of that approach. In the long run it is clearly better to have a two-ways supply system than to have areas that are only supplied by one pipe. However, this type of analysis might show that there are other pipes that are even more critical and needs to be prioritized, given a limited budget.

6.2 IMPLICATIONS FOR THE STRATEGIC LEVEL –THE STRATEGY PROCESS REPLAYED

In the previous chapter it was demonstrated how UNMET could be utilized to stress possible alternatives to the ones focused by the case utility. This approach will have as a consequence that the water utilities knowledge of status and reservoir of factual assessment criteria and potential metrics will increase. In itself, this will in turn open potential new avenues in future strategic process, or if the strategy process was replayed with this knowledge onboard.

The utility has a documented strategy, setting the focus and ambition for future priorities. This is the outcome of a process balancing various professional and political interests. The main weaknesses as compared to the PDCA hallmarks are lack of discussions about alternatives and lack of detailed diagnosis. The performed failure and CIMP analysis in previous chapter are adding knowledge and information to increase the option for discussions and diagnosis of infrastructure status as an input for deliberation of alternative strategic routes and action priorities.

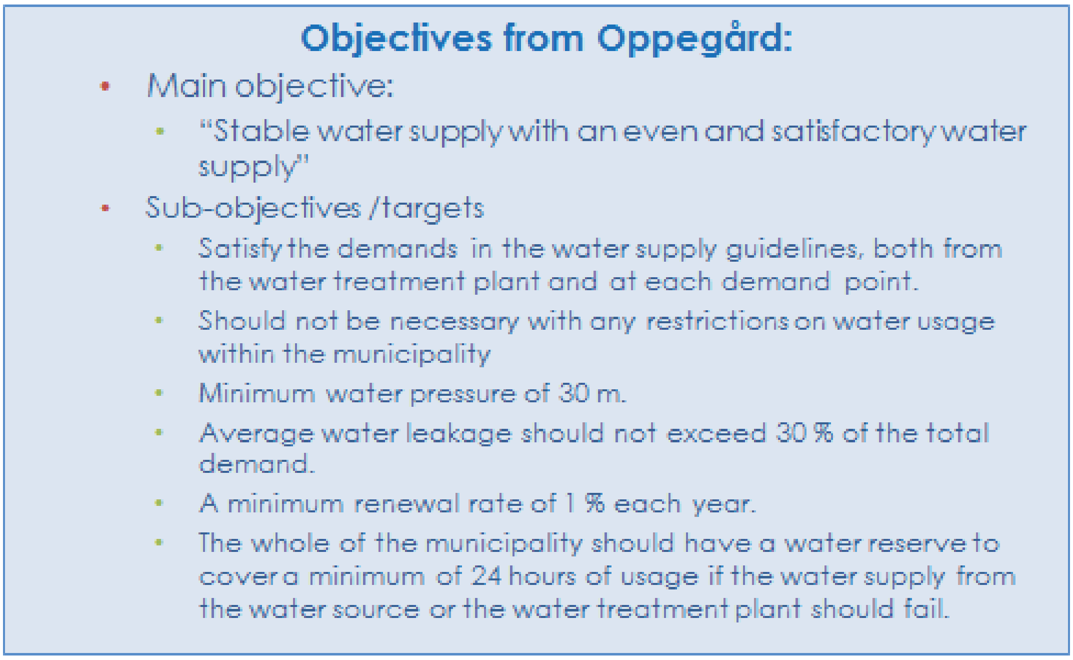


Figure 23 Objectives from Oppegård

However, in a collaborative and politically oriented planning situation there is a potential that the various actors have so strong vested interests in certain focus areas that an open exploration of possible alternatives are hampered, particularly if alternatives are seen as other actors passionate causes more than a well-argued factual based option.

Figure 23 presents objectives from the case utility. Given that they represent a balance of professional and political focus areas, it is difficult to argue that failure rates or various values for potential unmet demands in itself will have any significant effect on strategic deliberation, selection of strategic alternatives or alternative metrics.

However, with an easy access to all potential alternatives that they could have chosen, additional facts about their own infrastructure could get heavier weight and represent a similar approach as demonstrated on the tactical level, where – correctly utilized – smart tools can assist in “playing around” with alternatives to stimulate awareness of option and consequenses.

The right strategy for one water utility can of course be fairly different from another. At the same time there are equally obvious limits to this variation. Objectives will tend to cluster along a limited set of principal perspectives. ISO 24512:2007(E) is claiming that the objectives specified in the standard (ref, Clause 4 in the standard) *“are considered to be the principal objectives for drinking water utilities”*. The implication of this is that when the various actors meet in a strategic process, they are faced with selecting strategic routes, but within boundaries. If these boundaries could be presented in an easy way, illustrating options and designed for a collaborative process, then new alternatives, assessment criteria or metrics could more easily be embedded in the discussion. Maybe the most important point here is to visualize what they have opted out. It is easy to set an objective, but it is when somebody points out what you have chosen not to do it actually hurts. Based on what is documented in this study, there is reason to believe that alternatives opted out more frequently is due to lack of awareness and overview, than explicit choices made. A Strategic Option Map can solve this.

An example is presented in figure 25. This map is a first draft, limited to cover principal options for a drinking water utility, not including wastewater or in any details water treatment. An extention in order to include a broader scope than I am working on in this demo case will only be a matter of extending objective perspectives and add possible assessment criteria. For this case study, figure 25 contains what is needed to illustrate process potentials.

To be on sound technical ground, the map is entirely constructed based on standards and information content of ISO 24512:2007(E) and ISO 24510:2007(E).

Figure 26 shows the same map, but applied to the case utility. They have chosen “Provision of service under normal and emergency situations” as their main strategic perspective in the sense that main strategic objective belongs here. Complete in accordance with the ISO standard (see appendix C) they have also chosen assessment criteria from other perspectives; see red markings in figure 26.

The belonging of the additional assessment criteria introduced through the CIMP analysis in previous chapter is marked in green.

Using a simple framework for easy presentation of previous focus areas and new viable options based on improvements at tactical level, can thus be a trigger to a more serious analysis of alternatives. If at the same time tactical improvements strengthen factual knowledge of infrastructure condition and status, the motivation for a more thorough diagnosis and analysis of action alternatives via tools like SWOT or others can emerge.

It is difficult to argue that improved tactical analysis and simulations by itself will have an effect on this part of the strategic work. In order to embed PDCA in a water utility planning process it is on the one side, a matter of stimulating that this type of diagnosis is done. On the other side, it may be equally important that it is done in the right way. The AWARE-P/PDCA approach stresses heavily the need for a comprehensive and multi-disciplinary approach including all of the following; management, engineering and information. Documented SWOTs within reports from the AWARE-P initiative typically contains all of them in a fairly balanced way. For examples, see (Cardoso, et al., 2012). However, SWOT as made available as part of the case study is more limited. It seems that if you loose out on the multidisciplinary perspective already on the strategic diagnosis level, it will be hard to complete a significantly comprehensive approach to the asset management strategy.

In figure 24, this is illustrated with a simple underlining of the need to keep all of them in mind when working with the SWOT, and by pointing at the fact that the purpose of a SWOT is not the SWOT as such, but to dig out background information to complete a plan that describes 1) how strength and opportunities are utilized and 2) how threats and weaknesses are handled in order to reach the selected objectives.

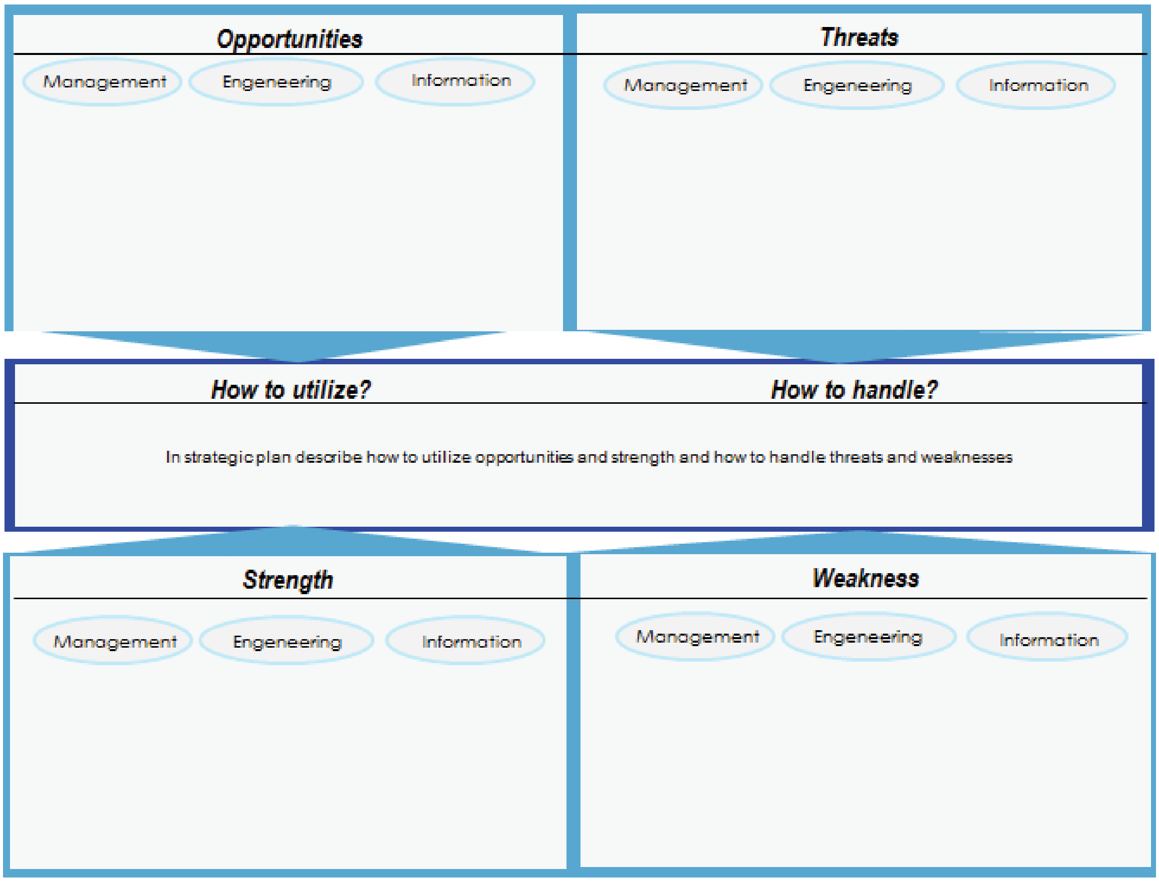


Figure 24 SWOT

Strategic options map

	Principle objectives for drinking water utilities. Objectives related to:					
	Protection of public health	Meet user needs and standards	Provision of service under normal and emergency situations	Sustainability of the water utility	Promote sustainable development of community	Protection of environment
Assessment criteria and corresponding performance indicators	Meet public health and drinking water quality standards	Provision of services	Provide continuous supply of drinking water tp users	Design distribution system capacity	Manage drinking water demand	Minimize natural water resource abstraction
	% meeting specified standards	Interruption per connection/1000 connections/year	Population coverage (%) Continuity of supply (%)	Treated water storage capacity (in days)	% lost by leakage	
	Meet thresholds or minimum microbiological, chemical or radiological quantities	Quantity of drinking water supply	Provide adequate pressure in distribution system	Keep infrastructure in good condition and optimize continuously (use current research and appropriate technology)	Be an integrated part of community development planning	Minimize energy consumed
	% meeting specified standards	Time with water use restriction in place	Pressure complaints (%)			
	Maintain system integrity	Contract management and billing	Maintain adequate quantity in distribution and treatment capacity	Quality management system certifications	Provide education and awareness programs	Minimize pollutants generated
		Service agreement complaints and queries (number/customer/year)		Certificate (Yes/no)		
	Maintain acceptable aesthetic qualities (taste, odor, color)	Promotion of good relationship with users	Meeting targeted risk levels	Occupational health protection and safety management certification		Environmental management system certification
	Water quality complaints (%)	Participation scheme with users (Yes/No)	Unmet demand	Certificate (Yes/no)		Certificate (Yes/no)
			Having a critical customer supply plan	Keep and develop a qualified labor force		
			Critical customers identified and updated plan documented	Documented competence and capacities GAPS		
			Keep assets in reserve			
			% of users covered by two-sided water supply.			

Figure 25 Strategic options map

Strategic option map for Oppegård

Criteria used by Oppegård

Criteria used in case study

Principle objectives for drinking water utilities. Objectives related to:

Assessment criteria and corresponding performance indicators

Protection of public health	Meet users needs and standards	Provision of service under normal and emergency situations	Sustainability of the water utility	Promote sustainable development of community	Protection of environment
Meet public health and drinking water quality standards	Provision of services	Provide continuous supply of drinking water to users	Design distribution system capacity	Manage drinking water demand	Minimize natural water resource abstraction
% meeting specified standards	Interruption per connection/1000 connections/year	Population coverage (%) Continuity of supply (%)	Treated water storage capacity (in days)	% lost by leakage	
Meet thresholds or minimum microbiological, chemical or radiological quantities	Quantity of drinking water supply	Provide adequate pressure in distribution system	Keep infrastructure in good condition and optimize continuously (use current research and appropriate technology)	Be an integrated part of community development planning	Minimize energy consumed
% meeting specified standards	Time with water use restriction in place	Pressure complaints (%) Deviation from minimum pressure (days)	Renewal rate (%) Failure rate (5)		
Maintain system integrity	Contract management and billing	Maintain adequate quantity in distribution and treatment capacity	Quality management system certifications	Provide education and awareness programs	Minimize pollutants generated
	Service agreement complaints and queries (number/customer/year)		Certificate (Yes/no)		
Maintain acceptable aesthetic qualities (taste, odor, color)	Promotion of good relationship with users	Meeting targeted risk levels	Occupational health protection and safety management certification		Environmental management system certification
Water quality complaints (%)	Participation scheme with users (Yes/No)	Unmet demand	Certificate (Yes/no)		Certificate (Yes/no)
		Having a critical customer supply plan	Keep and develop a qualified labor force		
		Critical customers identified and updated plan documented	Documented competence and capacities GAPS		
		Keep assets in reserve	Infrastructure value and aging degree		
		% of users covered by two-sided water supply.	Infrastructure value index		

Chosen principal strategic perspective

Figure 26 Strategic options map for the demo case utility

6.3 LESSONS LEARNED

The aim of the demo case study excersise conducted in this chapter was partly to experience and identify actual operational challenges that a utility will meet if implementing state of the art IAM support tools of AWARE-P character, and partly to run a compelling demonstration with real data from the case utility in order to prove potential benefits if modern IAM approaches is applied.

It is demonstrated that even with limited data, powerful analysis can be run with meaningful outcomes without too much difficulties. The most fruitful example is probably the option to create clear and easy-to-follow illustration of the specific benefits and cost of certain intervention solutions. This points at approaches to ease the work to come up with efficient solutions, and will also make it more convenient to produce a more detailed and scientifically oriented report that it is easier to defend and argue for.

Further, the link between the tactical and strategic level have been highlighted to show how the lower level is actually conducive to shape the upper. A minimum data-backed alternatives and interventions options on the tactical level, can be utilized to inspire the strategic process and the inclusion of more alternatives, broader perspectives and a required focus on metrics.

There is also no doubt that missing data and dubious data quality is a significant obstacle and an important showstopper when it comes to implement more powerful IAM approaches. Ways to compensate must be found in order to achieve a more widespread implementation.

We have also seen that traditional AM planning processes seems to have a tendency to be locked in a established pattern where a fairly narrow set of perspectives are dominating, either anchored in experience or in political considerations, each with their spokespersons. It is not necessarily the case that this leads to unproductive, wrong or hazarduous results, but to ensure that all relevant alternatives is duly considered, it is important to bring the process out of the box. It is demonstrated that this can be done by slightly amending how the plannings process is structured in practice. Utilizing analytical tools for simulations purposes and strategic option maps are the examples.

So, by this demo case study it is demonstrated that a more comprehensive AM approach undoubtly carries significant potential for benefits for decision improvements, but also that it is possible to utilize powerful tools without having a perfect dataset, meaning it is possible to get started. This is however, not sufficiently compelling to ensure implementation. There seems to be other sides that are equally important showstoppers. I am left with an impression that to some extent structured approaches and scientific tools also are seen as a potential threat to established work forms and organizational check and balances. Leaving more of the descision to complicated tools can equally be experienced as alienation than as valuable support. There is a desire or need to involve everyone in the planning process, from engineers to operational personnel and even politicians in a certain degree, which is difficult to do with complicated analytical tools.

7 EMBEDDING IAM IN MEDIUM AND SMALL NORWEGIAN WATER UTILITY – WAYS FORWARD

In this thesis it has been substantiated that water utilities in the developed world are facing serious asset management challenges and that this is equally applicable for Norway. The last decade several initiatives have taken to develop improved approaches and tools to support and strengthen the infrastructure asset management practises in the various utilities. There are strong indications that particularly in small and medium sized utilities there exists a large potential for improvement in how asset management is planned and operated. In Norway, the majority of the utilities are in the category small and medium. The implication of this is that highly required asset management improvements hardly will take place without getting this part of the industry onboard. 60% of the Norwegian population is served by water utilities providing water for less than 20 000 people (Myrstad, et al., 2011). For a complete overview of the structure of water utilities in Norway, see appendix D. In the demo case study performed to learn and experience the process of embedding IAM in a medium sized utility, it become evident that key personnel on a general level dimissed a comprehensive methodology for asset management, perceiving it as representing a fairly rigid and work demanding approach. Their opinion was also that they felt they had sufficient control and sufficient knowledge of status and future challenges. They felt their needs were more on detailed levels and specific issues like improved risk documentation and analysis that could support their practical planning approach.

I do not have sufficient data or information to judge anything about the actual situation in the case utility regarding operational efficiency and quality of assest management. However, what is documented is that their pracises are fairly in accordance with what is termed “traditional planning”. Neither do I have any information that the case utility stands out from the crowd in any particular way. So, to the degree that the case utility is representative, we basically have two options: Either they have not yet fully realized the potential long term implications of present regime, or the situation is somewhat less dramatic than what is advocated by experts and academics behind AWARE-P and the like.

We do not have sufficient facts or data to claim one or the other. Regardless, in this context it is not necessary to make this judgement to justify pointing at viable ways ahead. If the case utility is wrong and their practices today are not sufficient, then their need of supporting approaches to asset management sooner or later is going to be critical – which basically is AWARE-P’s argument. If on the other hand they are right, it is still reason to believe that improving the traditional approach can carry significant benefit. In previous chapter, it is documented that for instance strengthening their precision when choosing alternative courses of action could result in the same ability to maintain their water infrastructure, but with less resources in the long term. Another argument for evaluating improved practices, is the element of knowledge transfer. Small water utilities are hugely dependent on the non-documented experience of a few key personnel. With more focus on quality data collection and the use of structured models and planning processes, it will be easier for successors to continue a steady course.

To achieve more of what the experts behind AWARE-P are urging for, or at least increase the preparedness and robustness of AM practices, we learned in previous chapter that it is necessary to work along at least two axes:

1. Compensation of weak data and elimination of troubles and hazzle. I experienced myself that lack of date is a valid argument not to spend too much time on support initiatives like AWARE-P. A lot of cleaning and limited analytical options available speaks for it self. Along the same line is lack of a decent harmonization of basic datastructure, like pipe ID#, between the two most frequently used working tools.
2. Empowering their existing works forms and processes. Parts of the rejection are about how the analytical approach does not fit their ways of working and the collaborative approach within a political descision making culture.

The ways forward, as this demo case study has revealed, will need to build on answers along these two axes. The rest of the chapter will argue why and demonstrate options through examples.

The key conclusion that is possible to draw from the above, is that there is a need to reduce the threshold and sort of get on "speaking terms". Understand that many small or medium water utilities do not have the resources or motivation to invest in advanced and complicated asset management approaches and tools, and try to compensate for that.

7.1 COMPENSATION OF WEAK DATA AND ELIMINATION OF TROUBLES AND HAZZLE

As pointed out in chapter 6, the options available for analysis was significantly restricted due to lack of data. Other analysis than the one actually performed could also have been useful. As an example, a major focus has been pipe breaks since the risk for various kinds of breaks is a key indicator in planning for a water utility. We know that this is a function of various factors, of which pipe material, age and dimension are particularly significant. In the performed analysis only material could be included, and even here we have obviously weak data in that one of the material types could not be calculated.

It is well documented that lack of data is an important obstacle to systematic analysis and planning beyond the present situation. I have previously argued that this fact is an important driver to keep the water utilities in the vicious circle. My argument is therefore that any approach aiming at supporting water utilities planning processes need to take this fact into account, and should be able to offer some practical solutions. Specifying data needed in order to run important analysis and get vital answers to improve planning, is of limited use if the data just does not exist. Alternative options are particularly important since this type of data will take years to acquire. Let us use our case utility as an example. They have more or less systematically collected failure data for around 10 years if we look at their reported break data. It might have been a little on and off, but the calculations below support that it at least must be close to a time period like that. The absolute key question is then for how many years will the case utility have to continue to collect data to satisfy the requirements for analysis that are seen as necessary to satisfy recommendations from support systems like AWARE-P?

Some simple estimates and calculations reveal some discouraging answers, see table 12.

Table 12 Missing data findings

Material	MCU	Plastic	SJG	SJK	Unknown
Meter	15	8077	44189	61332	3251
Actual account of failure	0	0	75	11	1
Calculated failure rate	0	0	0,17	0,02	0
Reference fail rate1, Utah study		0,016	0,152	0,030	.-
Expected fail/year from actual meters			7,51	1,23	

During the first 10 years, the case utility has not registered breaks on plastic pipes. If we use as reference the fail rate of 0,016 from the Utah study (Folkman, 2012), they should expect a break each 7-8 years. So probably they will soon have one. One break is obviously a little weak, at least to say anything significant. To double it to two breaks they most likely will need close to another 10 years of registration, and still will not have data for any precise risk estimates. We also know that age and dimensions are additional significant influencers in this picture. If we add these two dimension in order to for instance to run a LEYP process we would need data within several subgroups. With the limited number of pipes and kilometres, small and medium sized utilities would need to continue registration for a long time periode before they could even start.

The only solution to this dilemma is that support software providers include some options for use of reference data in their solution. If a utility have few or no break data from their own infrastructure it should be possible to use a standard set of quality assured failure rates broken down in key subgroups. Preferably, the rates should be accompanied by a typical range depending on soil and other external factors. Selection within a range should be possible by users utilizing local knowledge. If a utility have a fair set of data, the solution should automatically display a comparison opening for a sound professional judgment to be used.

One way is to make use of generic failure rates estimates calculated in previous studies. One example is by utilizing what is available from the comprehensive studies as the one performed by Utah University of the state of the water networks in the USA and Canada that has estimated failure rates based on material types (Folkman, 2012).

The limitation of this approach is that the data extracted from other sources might not be completely accurate for their specific network. However, where there is no data available or they have a limited number of events, this approach can both help a water utility to calibrate or get a better understanding of their own data and give them an opportunity to have some approximations where there is no data available. To me it seems that an easy access to accumulated or combined data from other sources is essential to limit the threshold of using advanced analysis and getting better results with what is available at the water utility.

One step further is the approach seen in the SIROCO project where it is proposed the use of an amalgated database. By using an amalgated or combined database for many or all small, medium or even large water utilities in Norway, it is possible to utilize this to calculate failure rates and remaining service life where a specific water utility might have insufficient data or registrations. As mentioned above, this data can be broken down in key sub-groups, e.g. soil type or water quality, that will enable a water utility with good local knowledge to select failure rates range based on their situation. Another benefit of this amalgated database is that it can be used as a benchmarking tool. The water utilities can see how they do, compared to others.

7.1.1 HARMONIZATION OF DATA – ELIMINATE HAZZLE

Another difficulty that was made apparent when trying to utilize the AWARE-P toolbox on a tactical level, was the discrepancy between datasets. In this particular case, it was the incongruity between the pipe ID# in Gemini VA and Epanet. This made it impossible to perform a good and reliable unmet demand analysis without a significant amount of work. If it is a desire to implement a service interruption risks analysis with the UNMET model, this needs to be remedied.

One solution is to create a sort of intermediate database. What is meant by this is a database that combines all the pipes in one pipe section, from manhole to manhole or node to node, into one ID# that makes is possible to have the same pipe ID# in this intermediate database and the Epanet model. The characteristics for this "combined pipe" must naturally be dependent on the "worst" pipe in the pipe section, the pipe most prone to failure. This type of intermediate database would have made it possible to perform a reliable unmet demand analysis for the case utility, while also see the impact the rehabilitation of the pipes that is already selected in the rehabilitation plan for the case utility would have on the service interruption risk metric.

7.2 PROCESS SUPPORT – THE OFFERING OF A DECISION THEATER

From the interviews in the case utility it was found that they strongly believe in their collaborative approach and have an impression that the recent IAM initiatives represents a too rigid, top-down expert approach. A route where experts or consultant use the available data and information to decide intervention solutions, is not the way to go. They believe that involving personnel from all layers of the organisation, engineers to operational personnel, is important to be able to both select the best solutions, but also to best implement what is chosen and build competence.

A way to accommodate this could be to use decision support solutions as a sort of pedagogical or collaborative process support tool. What this means, is a work form and system-support that is able to feed information and knowledge into a planning process in real time to stimulate thinking and reflection while giving valuable input. This is in contrast to just as an "academic" system that gives the user an answer. A benefit of this type of decision support system is that it enables the utility to involve personnel from all layer of the organisation, as was the desire of the case utility, instead of just one or more analysts using their knowledge and expertise to decide a solution and create planning documents.

The creation of this type of collaborative process support tool, or what we could term a decision theatre, is possibly the most important element and fundamental when trying to lower the threshold for small or medium water utilities and motivate more use of analytical tools and models.

A decision theatre is about designing and utilizing high quality calculations, not primarily to get the correct conclusion from the answer book, but as an assistance to simulate, test, play with scenarios and vizualise options. Such an approach will guide and support the users in their already established planning process, not demanding a complete new set of tasks and roles. Let us look at some simple examples that emerged as useful in the demo case in previous chapter.

7.2.1 TACTICAL LEVEL – REHABILITATION PLANNING SUPPORT

As we have seen in previous chapters, the AWARE-P toolbox includes some powerful tools and models that enables both a water utility to compare alternative interventions solutions and create a prioritized list of pipes to rehabilitate based on specific metrics. It is little doubt that the tools in the AWARE-P toolbox that has been presented and used in this report, can give important input for a planning process. We have seen that the tool CIMP, FAIL and UNMET is capable of giving an understanding of the system; which areas are vulnerable, which pipes has the highest risk of failure etc. What they do require however, is the organized importing of the original data tables and Epanet network model, in addition to the same type of data tables and network models for different alternatives if the desire is to compare.

If you for instance did what was done in the example of using the AWARE-P tools earlier in the report and used UNMET to prioritize pipes, you would still need to create an alternative work order table for FAIL to calculate the new unmet demand. This is somewhat time consuming and is difficult to do in real-time in a planning meeting situation.

A functionality that could fix this and make it more user friendly for a meeting and collaborative environment would be an option to select, directly in the software, which pipes from the prioritized list in UNMET should be rehabilitated to see the effect. If the software also includes an option to select an approximate cost per meter pipe, it can also give an estimation of cost. Another element could be that if it for some reason is, for example due to synergies with other projects, desired to rehabilitate one or more pipe that is not listed in the UNMET prioritization, an option to select this pipe straight away in the program without having to change and upload new data tables will increase the usefulness of the AWARE-P project in this “brainstorming” rehabilitation process.

7.2.2 STRATEGIC LEVEL - STRATEGIC PLANNING WIZARD

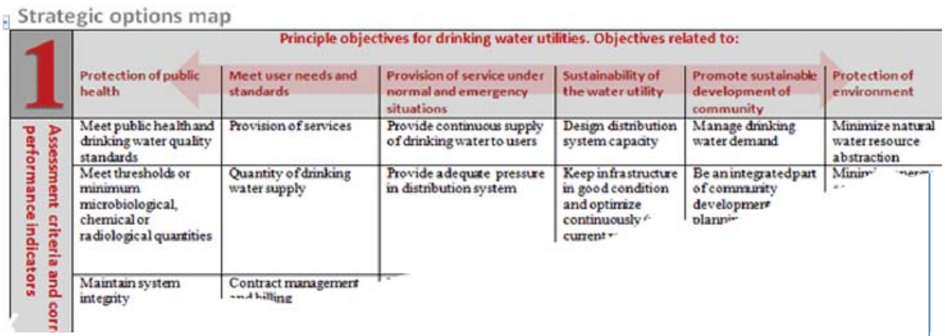
In a collaborative politically oriented culture the strategy is shaped in a process involving a wide range of people. With limited experience and knowledge from systematic strategic planning, but the more experience with what was termed called classic planning there is a substantial threshold to move from one to the other. In a situation with limited resources and expectations that the good old approach is good enough, the incentives not to change is substantial. To turn, the threshold must be reduced. It must be easy to present and follow a step-by-step planning process and the steps must be adapted to collaborative approach. Well established knowledge must be easy available in a way that it can be utilized in interaction with own experience, and the steps must route you through the required consideration. We are talking about some kind of a planning wizard and decision support solution.

Within the framework of this thesis a complete specification for a solution cannot be provided. However, to illustrate the argument and how it relates to the present finding, let me present an example. We found in the case study that particularly the strategic phases needed profound diagnosis and discussion of alternatives, is a challenging point. It is my impression that this is due to lack of experience, lack of data and not least lack of information about possible and viable alternatives, perspectives and practical ways of assessing and/or measuring. If you do not have a clear picture of the route and you do not know how to cross the obstacles you are sure to meet, it is probably fair to decide not to waste time on it, what we do is good enough.

Table 13 Four steps to illustrate the decision support

Startegic options – vizualize the playing ground

Imagine a mixed group of people discussing possible objectives. What should be our long-term aim? Some have and some do not have vested interests or ready-made suggestions. If they had had an authoritative source with possible alternative routes, it would shape the discussion by clarifying the yardsticks of the playing gound. The first part of the strategic option map provides an example.



Strategic options map

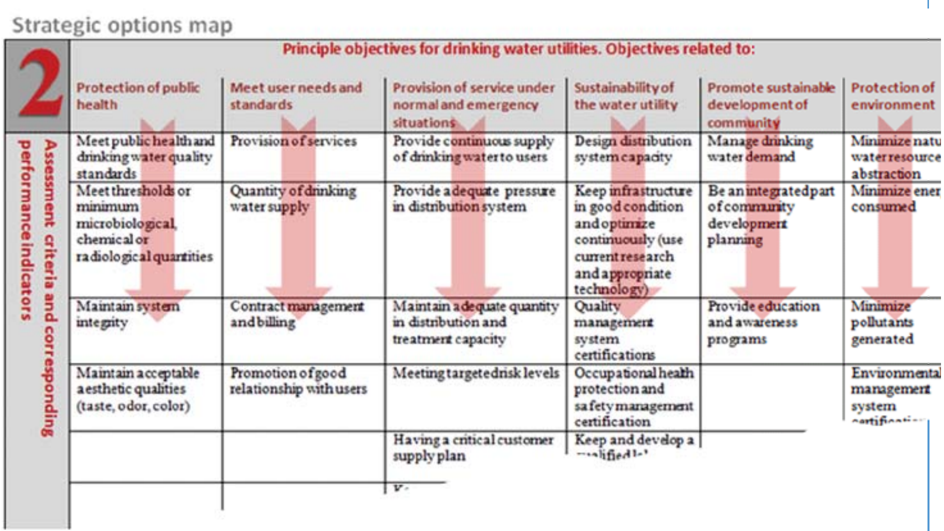
1	Principle objectives for drinking water utilities. Objectives related to:					
	Protection of public health	Meet user needs and standards	Provision of service under normal and emergency situations	Sustainability of the water utility	Promote sustainable development of community	Protection of environment
Assessment criteria and cor performance indicators	Meet public health and drinking water quality standards	Provision of services	Provide continuous supply of drinking water to users	Design distribution system capacity	Manage drinking water demand	Minimize natural water resource abstraction
	Meet thresholds or minimum microbiological, chemical or radiological quantities	Quantity of drinking water supply	Provide adequate pressure in distribution system	Keep infrastructure in good condition and optimize continuously current	Be an integrated part of community developmer plann	Minim
	Maintain system integrity	Contract management				

It is all about navigation

Imagine further that during the discussion there is a need to view options for assessments or how it should be followed up. Do we satisfy the conditions to do it properly?

It should be easy to open and have a preview of alternatives, by expanding the objectives under discussion.

Typically this type of deliberation will have an iterative character, going up and down between step one and two, or even the third shown below - what kind of metrics could we use?



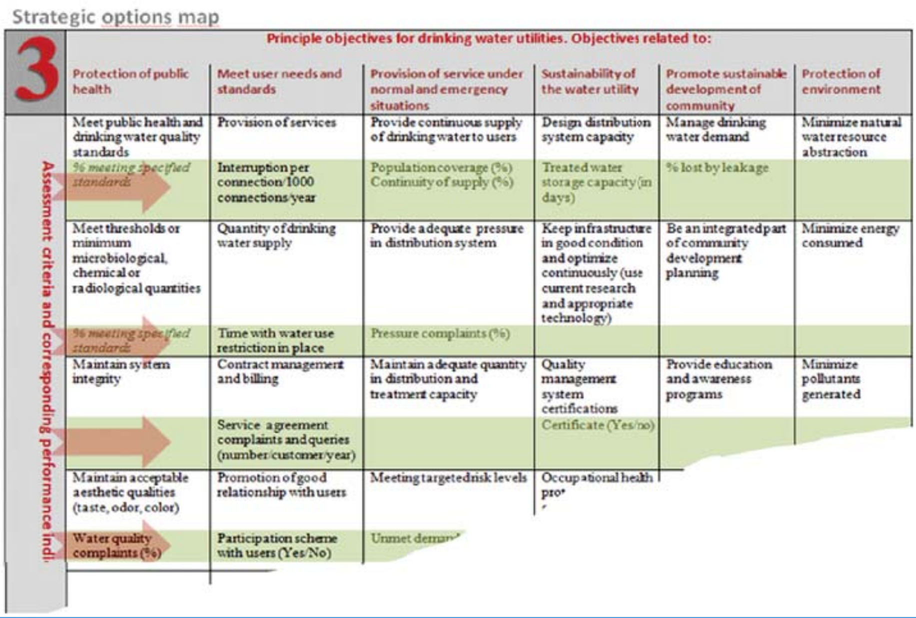
Strategic options map

2	Principle objectives for drinking water utilities. Objectives related to:					
	Protection of public health	Meet user needs and standards	Provision of service under normal and emergency situations	Sustainability of the water utility	Promote sustainable development of community	Protection of environment
Assessment criteria and corresponding performance indicators	Meet public health and drinking water quality standards	Provision of services	Provide continuous supply of drinking water to users	Design distribution system capacity	Manage drinking water demand	Minimize natu water resource abstraction
	Meet thresholds or minimum microbiological, chemical or radiological quantities	Quantity of drinking water supply	Provide adequate pressure in distribution system	Keep infrastructure in good condition and optimize continuously (use current research and appropriate technology)	Be an integrated part of community development planning	Minimize ener consumed
	Maintain system integrity	Contract management and billing	Maintain adequate quantity in distribution and treatment capacity	Quality management system certifications	Provide education and awareness programs	Minimize pollutants generated
	Maintain acceptable aesthetic qualities (taste, odor, color)	Promotion of good relationship with users	Meeting targeted risk levels	Occupational health protection and safety management certification		Environmental management system
			Having a critical customer supply plan	Keep and develop a		

If you cannot measure, you cannot manage

AWARE-P put heavy emphasis on metrics. It will feel like waste of time to re-invent the wheel in every utility. Any support solution should have a fair selection ready at hand.

Discussing possible assessment criteria linked to an objective of interest, possible metrics should only be a "click away".

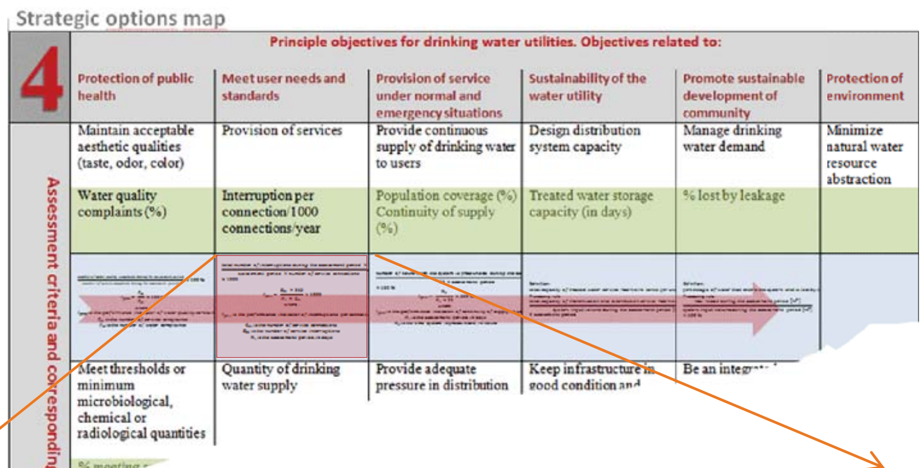


The math needs to be done

When decided it should be easy to get some inspiration on how to do it in practice.

A metric should be described, precisely defined and sufficiently illustrated to ease implementation.

For more examples of metrics described and defined,
see appendix E



Definition:

$$\frac{total\ number\ of\ interruptions\ during\ the\ assessment\ period\ \times 365}{assessment\ period\ \times number\ of\ service\ connections} \times 1000$$

Processing rule:

$$I_{QS14} = \frac{D_{35} \times 365}{H_1 \times C_{24}} \times 1000$$

where:

I_{QS14} *is the performance indicator of*

interruptions per connection, in $\frac{number}{1000\ connections/year}$

7.3 CONCLUSION

It has been performed a demo case study with the purpose of simulating and experiencing the embedment of a comprehensive IAM methodology whitin the reality of a water utility. The demo gave rise to meet technical challenges and demanded analytical skills to perform decent evaluations. Further, it was an opportunity to experience the beauty and benefit of proper analysis and calculations. However, at the end of the day, the overriding lesson learned through this demo process is that encasing sound IAM practises is not just about implementing and use comprehensive tools and methodologies, it is about supporting people.

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APPENDIX A, CONDITION ASSESSMENT OF NORWEGIAN MUNICIPAL WATER UTLITIES

Norsk Vann, an interest group for water and wastewater, has done a condition evaluation of Norwegian municipalities' water and wastewater services. This is presented in the report called "Tilstandsvurdering av kommunale vann– og avløpstjenester".

For this appendix it has been extracted four pages from the report that shows the condition or situation of the municipalities' services when it comes to water supply. The results for Oppegård is highlighted with red frames.

Source:

Norsk Vann, 2011. *Tilstandsvurdering av kommunale vann- og avløpstjenester.* [Online] Available at http://norskvann.no/images/olel/BedreVA_resultatrapport_2011_data.pdf [Accessed February 2013]

Vannforsyning - Standarden på kommunenes tjeneste i 2011

Kommune	Innbyggere tilknyttet tjenesten	KI	Hygienisk betryggende vann	Bruksmessig vannkvalitet	Leverings-stabilitet	Alternativ forsyning	Ledningsnettets funksjon
Vekting i kvalitetsindeks (KI)			40%	15%	15%	10%	20%
Klepp	14300	4,0					
Ullensaker	30303	4,0					
Nesodden	16403	4,0					
Elverum	16847	4,0					
Hvaler	3261	4,0					
Randaberg	10256	3,6					
Moss	29965	3,6					
Oppegård	24000	3,6					
Gjerdrum	4500	3,6					
Tromsø	64136	3,6					
Nøtterøy	20995	3,6					
Narvik	17354	3,6					
Bærum	113625	3,6					
Sandefjord	42690	3,6					
Stavanger	127506	3,6					
Asker	52700	3,6					
Porsgrunn	35219	3,6					
Røyken	18020	3,6					
Øvre Eiker	15284	3,6					
Sandnes	56883	3,6					
Sola	22877	3,6					
Åseral	533	3,6					
Stjørdal	14200	3,4					
Kristiansand	78524	3,4					
Stange	15790	3,4					
Karmøy	37800	3,4					
Larvik	40110	3,3					
Alstahaug	7100	3,3					
Drammen	63699	3,3					
Ås	16000	3,3					
Bergen	256000	3,3					
Arendal	39500	3,2					
Søgne	9800	3,2					
Oslo	603285	3,2					
Trondheim	170000	3,2					
Aurskog-Høland	11442	3,2					
Skien	50487	3,2					
Sula	7675	3,2					
Hamar	26087	3,2					
Nordre Land	2856	3,2					
Løten	5126	3,2					
Øyer	2708	3,2					
Nord-Odal	873	3,2					
Lardal	1456	3,2					
Fjell	13920	3,1					
Molde	23400	3,1					
Kongsvinger	15327	3,0					
Østre Toten	13550	3,0					
Fredrikstad	70463	3,0					
Vågå	1858	3,0					
Namsos	10700	2,9					
Våler i Hedmark	2280	2,9					
Grue	4000	2,9					
Ålesund	42124	2,8					
Øystre Slidre	708	2,8					
Sarpsborg	51513	2,8					
Skedsmo	48752	2,6					
Lørenskog	33609	2,6					
Bykle	790	2,6					
Suldal	2495	2,5					

Vannforsyning - Standarden på kommunenes tjeneste i 2011

Kommune	Innbyggere tilknyttet tjenesten	KI	Hygienisk betryggende vann	Bruksmessig vannkvalitet	Leverings-stabilitet	Alternativ forsyning	Ledningsnettets funksjon
Vekting i kvalitetsindeks (KI)			40%	15%	15%	10%	20%
Ringebu	2644	2,5					
Bamble	13387	2,4					
Sørum	12378	2,4					
Lier	18450	2,4					
Ringerike	25675	2,4					
Ringsaker	24327	2,4					
Fusa	1030	2,1					
Rælingen	16050	2,0					
Harstad	20359	1,4					

Vurderingskriterier for standard på vannforsyningen

God:

4 poeng i kvalitetsindeksen

- Hygienisk: 100 % av innbyggerne tilknyttet den kommunale vannforsyningen har hygienisk betryggende drikkevann
  Vannforsyningen er beskyttet mot forurensning i kilde/nedbørfelt og gjennom vannbehandlingen og har dokumentert god hygienisk kvalitet
- Bruksmessig: 100 % av innbyggerne tilknyttet har god bruksmessig kvalitet. Kravene til pH og farge er tilfredsstilt
- Leveringsstabilitet: Ikke planlagte avbrudd i trykkvannsforsyningen er < 0,5 timer i snitt pr. innbygger pr. år og totale avbrudd er < 1,0 time i snitt
- Alternativ: 100 % av innbyggerne, som får vann fra vannverk > 1000 innbyggere, har gode alternative forsyningsmuligheter som kan levere i inntil 3 måneder
- Ledningsnettet: Beregnet vanntap er < 20 % av den totale vannmengden som er produsert og levert på distribusjonsnettet

Dårlig:

0 poeng i kvalitetsindeksen

- Hygienisk: > 10 % av innbyggerne tilknyttet eller > 1000 personer har ikke hygienisk betryggende drikkevann. Beskyttelsen mot forurensninger i kilde, nedbørfelt og/eller vannbehandling er for dårlig og/eller det er målt tarmbakterier i flere prøver på nettet
- Bruksmessig: > 25 % av innbyggerne tilknyttet eller > 5000 personer har dårlig bruksmessig vannkvalitet. Kravene til pH og/eller farge overholdes stort sett ikke over året
- Leveringsstabilitet: Ikke planlagte avbrudd i trykkvannsforsyningen er > 1,0 time pr. innbygger i gjennomsnitt pr. år
- Alternativ: > 25 % av innbyggerne eller > 5000 personer, som får vann fra vannverk > 1000 innbyggere, har ingen alternativ forsyningsmulighet eller at den alternativ forsyningen har for dårlig kvalitet
- Ledningsnettet: < 0,5 % av det totale ledningsnettet blir fornyet i året (beregnet som gjennomsnittet for de siste tre årene) og beregnet vanntap er > 40 % eller antall lekkasjereparasjoner på nettet er > 0,10 pr. km, år

Mangelfull:

2 poeng i kvalitetsindeksen

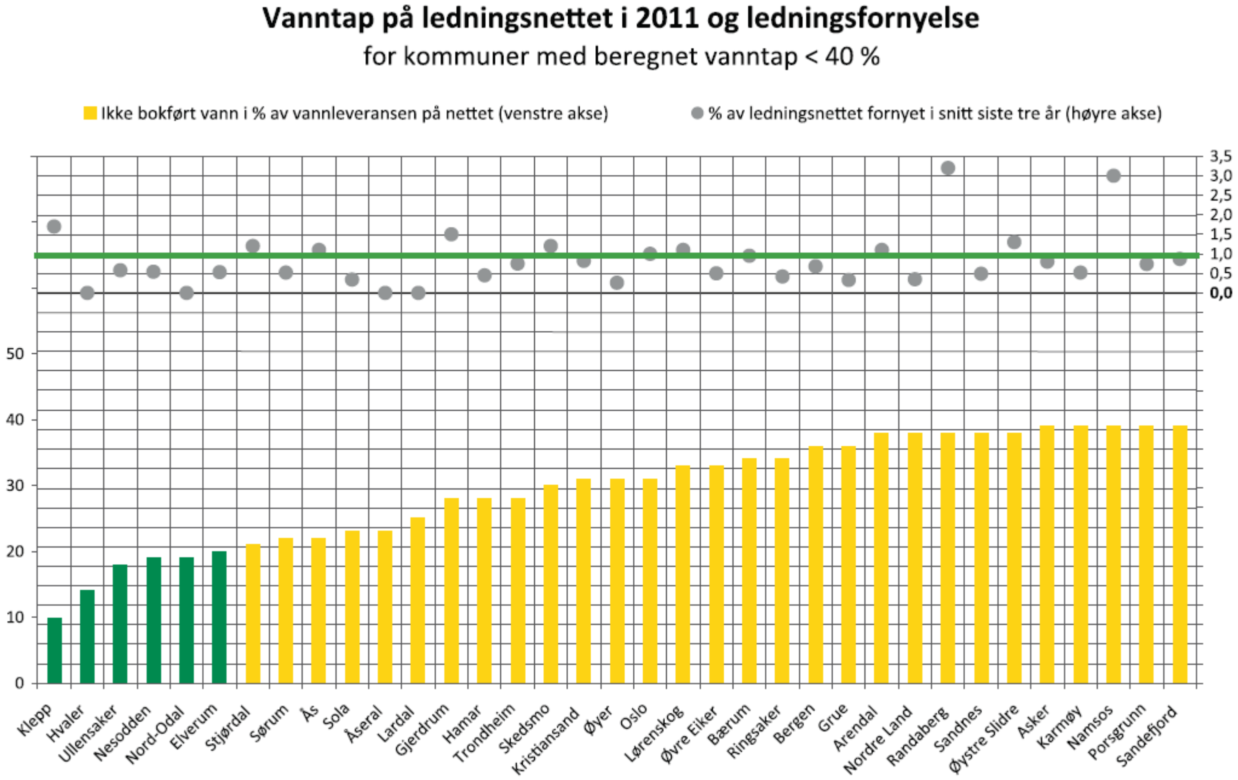
Standard som ligger mellom kriteriene for God og Dårlig

Beregning av kvalitetsindeks for vannforsyning

I tabellen over er kommunene rangert etter en beregnet kvalitetsindeks, som tar hensyn til at de fem vurderingsområdene har ulik vekting. Tabellen under viser et eksempel på beregning av kvalitetsindeks for en kommune. Dersom alle vurderingsområdene har fått vurdering God, blir kvalitetsindeksen 4,0.

Vurderingsområdet	Kode	Vekt %	Poeng i kvalitetsindeksen iht. vurdering				
			God	Mangelfull	Dårlig	Ikke krav til dokumentasjon	Mangler data
			4	**2**	**0**	**4**	**0**
Hygienisk betryggende vann	H	**40 %**					
Bruksmessig vannkvalitet	B	**15 %**					
Leveringsstabilitet	S	**15 %**					
Alternativ forsyning	A	**10 %**					
Ledningsnettets funksjon	L	**20 %**					
Kvalitetsindeks:	**H 40%*4 + B 15%*4 + S 15%*0 + A 10%*2 + L 20%*0 = 2,4**						

Vannforsyning - de største utfordringene



Figuren viser beregnet vanntap inkl. tap i private stikkledninger, i % av vannleveransen på ledningsnettet og hvor stor andel av vannledningsnettet som i gjennomsnitt er fornyet de siste tre årene. Kommunene som har grønne stolper har akseptabelt vanntap (< 20 %), mens kommunene med gule stolper har beregnet vanntapet til < 40 % Den grønne horisontale streken angir 1 % ledningsfornyelse.

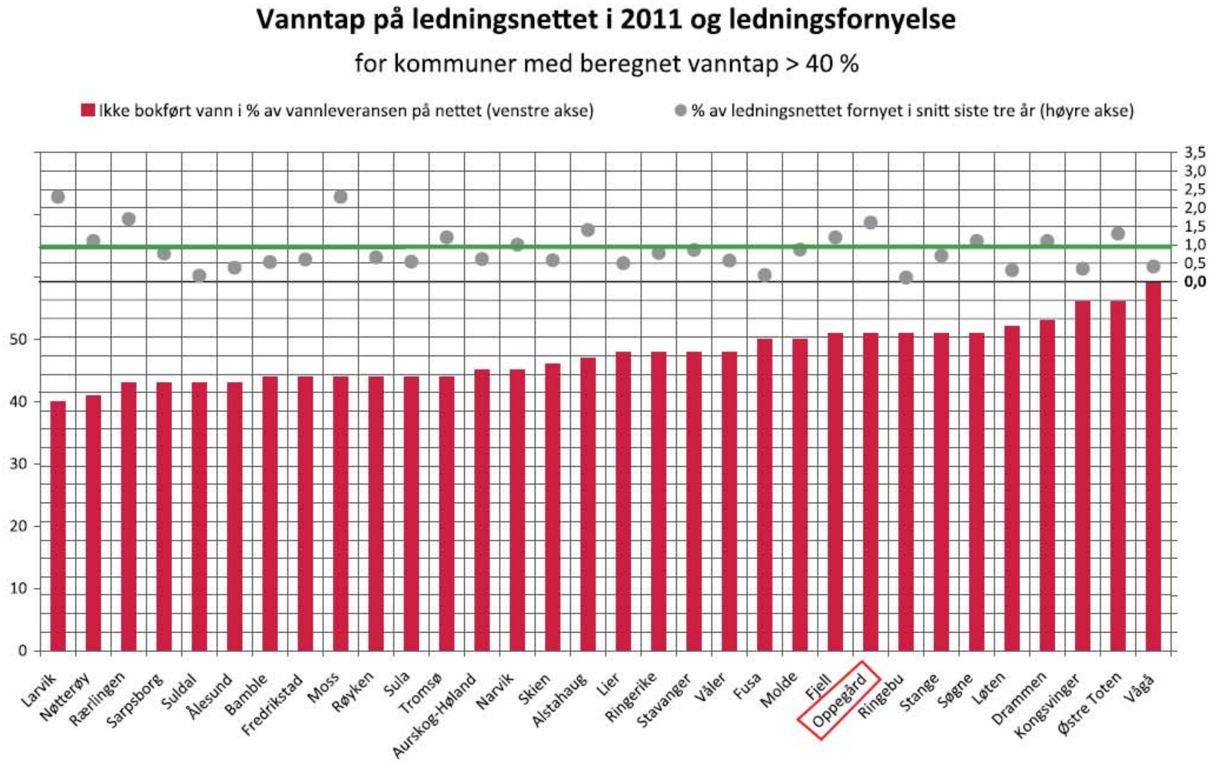
Reduksjon av vanntapet

Figuren over viser såkalt "Ikke bokført vann" i 2011 som er en indikator for omfang av vanntap på ledningsnettet. Ikke bokført vann er differansen mellom produsert vannmengde og mengde vann som er målt eller stipulert som forbruk for de ulike abonnentgrupper, samt offentlig vannforbruk. Denne metoden gir en indikasjon på den totale lekkasje-andelen i kommunalt nett og private stikkledninger og anboringer. For husholdningsabonnenter og fritidsboliger der vannforbruket ikke er målt, er det for 2011 benyttet 160 liter pr. person og døgn i beregningen av forbruket, mot 150 l/p,d i 2010. For fritidsboliger regnes 35 bruksdøgn pr. år i snitt.

48 % av kommunene har beregnet vanntap på over 40 % (49 % i 2010) og bare 9 % har beregnet vanntapet til mindre enn 20 % (10 % i 2010). Andelen kommuner som måler husholdningsforbruket har økt siden 2010. I 2011 er det ca. 40 % av kommunene som har vannmålerdekning på over 70 % mot 30 % i 2011. Dette øker sikkerheten i beregningen av vanntapet. Stipulering av vann-forbruk for abonnenter uten vannmåler er en stor usikkerhetsfaktor, da reelt forbruk kan variere med type bebyggelse. Ikke alle kommuner ønsker å øke vannmålerandelen hos husholdningsabonnentene, så utfordringen for disse kommunene blir å framskaffe mer dokumentasjon på vannforbruk i ulike typer boligområder for abonnenter uten vannmåler.

Det har blitt mer fokus på lekkasjekontroll og lednings-fornyelse i mange kommuner, så vi må håpe at vanntapet går ned i årene som kommer. For de kommunene som har deltatt i resultatmålingene i regi av Norsk Vann i perioden 2003-2011, er det imidlertid kun et fåtall som har redusert lekkasjene. En hovedutfordring for kommunene er også lekkasjene på stikkledningsnettet som er privat. For å redusere det totale vanntapet, må også det private stikkledningsnettet fornyes.

Vannforsyning - de største utfordringene



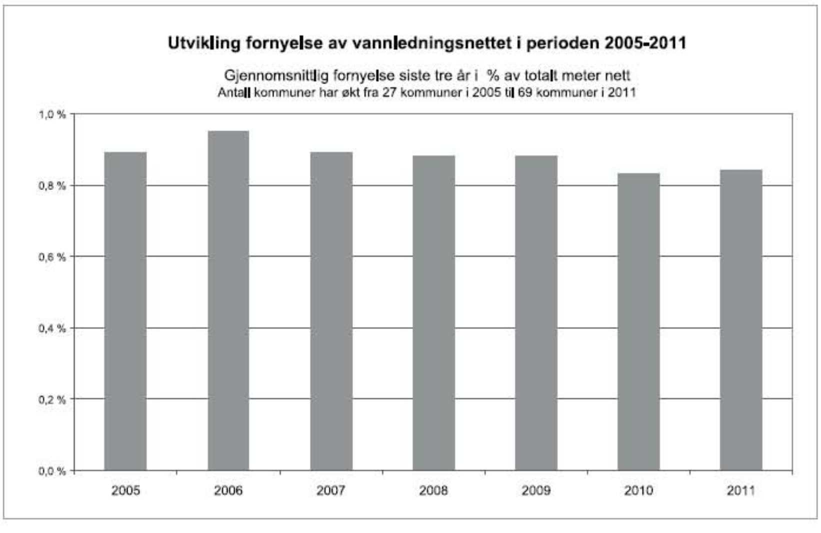
Figuren viser beregnet vanntap inkl. tap i private stikkledninger, i % av vannleveransen på ledningsnettet og hvor stor andel av vannledningsnettet som i gjennomsnitt er fornyet de siste tre årene. Kommunene med røde stolper har vanntap > 40 %. Den grønne horisontale streken angir 1 % ledningsfornyelse.

Kommuner med stor innsats på lednings-fornyelse

Aktiv lekkasjekontroll, trykkreduksjon og systematisk fornyelse av det dårligste ledningsnettet er tiltak som er viktige for å få redusert vanntapet. Til tross for problemet med stort vanntap har de fleste kommunene en ledningsfornyelse langt under 1 %. Det er imidlertid unntak og kommuner som peker seg særlig positiv ut.

De 10 beste kommunene er Randaberg (3,2 %), Namsos (3,0 %), Larvik (2,3 %), Moss (2,3 %), Rælingen (1,7 %), Klepp (1,7 %), Oppegård (1,6 %), Gjerdrum (1,5 %), Alstahaug (1,4 %) og Øystre Slidre (1,3 %). Tallet i parentes er gjennomsnittlig fornyelse siste tre år. Gjennomsnittet for alle deltakerkommunene er 0,84 %.

Figuren til høyre viser samlet gjennomsnittlig ledningsfornyelse av vannledningsnettet siste tre år og utviklingen av dette for deltakerkommunene i perioden 2005-2011. Til tross for utfordringen med stort vanntap i mange kommuner, er det i gjennomsnitt ingen økning i ledningsfornyelsen. Deltaker-kommunene i bedreVA har imidlertid noe høyere fornyelses-takt enn landsgjennomsnittet, som iht. KOSTRA er 0,6 % for perioden 2009-2011.



APPENDIX B, EXAMPLES OF METRICS ON THE TACTICAL LEVEL

Cost	
C1: Investment cost	Representing the economic effort in terms of investment in the network during the analysis period.
C2. Comparative design efficiency	This cost indicator is assessed as the ratio between the replacement cost of the network designed as the alternative under analysis and the replacement cost of the existing network. This shows whether the new configuration is closer to a minimum cost configuration that the existing network.
C3: Infrastructure value index	This cost index represent the ratio between the current value and the replacement value of the infrastructure. Should ideally be near 0.5
Performance	
P1: Minimum pressure under normal conditions	This performance index measures the demand locations that are supplied under the required pressure conditions. Can be assessed by the use of hydraulic simulation models.
P2: Minimum pressure under emergency conditions.	Similar to P1, but is used to evaluate pressure at demand nodes under emergency operations conditions. This is when the normal water source to a District Metering Area (DMA) fails and an alternative entry point is needed. Can be assessed by the use of hydraulic simulation models.
P3: Percentage of total pipe length in asbestos cement.	*Probably not applicable for Oppergård*
Risk	
R1: Risk of service interruption	E.g.: Estimating likelihood of pipe failure using failure rates computed per pipe material; pipe failure consequence estimating using component importance model that computes the impact of each pipe's individual failure (% of total demand not supplied), based on hydraulic simulation. Converting pipe failure and likelihood and consequence into different classes and then calculating R1 as the percentage of pipes in the moderate or high risk levels.

APPENDIX C, EXAMPLES OF SERVICE ASSESSMENT CRITERIA RELATED TO THE DRINKING WATER UTILITY OBJECTIVES

This table is taken from ISO 24512:2007(E), and shows examples of objectives and related service assessment criteria for a drinking water system. ISO 24512:2007(E) states that many service assessment criteria may be applicable to more than one objective. The examples given are considered to represent a direct relationship between objectives and assessment criteria.

ISO 24512:2007(E)

Table E.1 — Examples of objectives and directly related service assessment criteria for a drinking water system

Assessment criteria	**Objective**		
	Protection of public health	Meet users' needs and expectations	Provision of service (under normal and emergency situations)
Meet public health and drinking water quality standards	✓	✓	✓
Maintain system adequate quantity of drinking water	✓	✓	✓
Maintain a positive pressure in the distribution system	✓	✓	✓
Legal access to water source		✓	✓
Manage drinking water demand		✓	✓
Minimize pollutants generated	✓	✓	
Minimize energy used		✓	
etc.			

APPENDIX D, OVERVIEW OF THE DISTRIBUTION OF NORWEGIAN WATER UTILITIES BY SIZE

This table is taken from a report from the Norwegian Institute of Public Health. It shows the distribution/structure of Norwegian water utilities by size. The first table is the original, in Norwegian, the second is a rendering in English.

Source:

Myrstad, L., Nordheim, C. F., & Einan, B., 2011. *Rapport fra Vannverksregisteret.* [Online] Available at http://www.fhi.no/dokumenter/0d34aeb796.pdf [Accessed May 2013]

Vannverks-størrelse	Kommunal		Interkommunal		Privat/Statlig		Sum	
	Antall vannverk	Antall personer	Antall vannverk	Antall personer	Antall vannverk	Antall personer	Antall vannverk	Antall personer
<100 pers.	120	8 100	0	0	160	10 200	280	18 300
100 - 299	247	44 700	1	200	219	32 300	467	76 800
300 - 999	265	139 700	3	2 000	122	62 400	390	204 200
1 000 - 4 999	204	422 000	3	7 900	46	91 200	253	521 100
5 000 - 19 999	101	726 200	6	73 400	2	16 900	109	794 700
>=20 000	39	1 707 900	9	919 800	0	0	48	2 649 700
Sum	**976**	**3 048 600**	**22**	**1 003 200**	**549**	**213 000**	**1 547**	**4 264 900**
Andel	63 %	71 %	1 %	24 %	35 %	5 %	100 %	100 %
Gjennomsnitts-størrelse		3 123		45 600		387		2 757

Size of water utility [persons]	Municipal		Intermunicipal		Privat/central governmental		Total	
	Number of water utilities	Number of persons	Number of water utilities	Number of persons	Number of water utilities	Number of persons	Number of water utilities	Number of persons
<100	120	8100	0	0	160	10 200	280	18 300
100-299	247	44 700	1	300	219	32 300	467	76 800
300-999	265	139 700	3	2000	122	62 400	290	204 200
1000 - 4999	204	422 000	3	7900	46	91 200	253	521 100
5000 – 19999	101	726 200	6	73 400	2	16 900	109	794 700
>= 20000	39	1 707 900	9	919 800	0	0	48	2 649 700
Sum	**976**	**3 048 600**	**22**	**1 003 200**	**549**	**213 000**	**1547**	**4 264 900**
Andel	63 %	71 %	1 %	24 %	35 %	5 %	100 %	100 %
Average size		3123		45 600		387		2 757

APPENDIX E, EXAMPLES OF METRICS, FROM ISO 24510:2007(E) AND ISO 24512:2007(E)

1. Interruptions per connection

Performance indicator:

$$\textit{Interruptions per connection}\left[\frac{number}{1000\ connections/_{year}}\right]$$

Definition:

$$\frac{total\ number\ of\ interruptions\ during\ the\ assessment\ period\ \times 365}{assessment\ period\ \times number\ of\ service\ connections} \times 1000$$

Processing rule:

$$I_{QS14} = \frac{D_{35}\ \times 365}{H_1\ \times\ C_{24}} \times 1000$$

$$where:$$

$$I_{QS14}\ is\ the\ performance\ indicator\ of\ interruptions\ per\ connection, in\ \frac{number}{1000\ connections/_{year}}$$

$$C_{24}\ is\ the\ number\ of\ service\ connections$$

$$D_{35}\ is\ the\ number\ of\ service\ interruptions$$

$$H_1\ is\ the\ assessment\ period, in\ days$$

2. Continuity of supply:

Performance indicator:

Continuity of supply [%]

Definition:

$$\frac{number\ of\ hours\ when\ the\ system\ is\ pressurised\ during\ the\ assessment\ period}{24\ \times assessment\ period} \times 100\ \%$$

Processing rule:

$$I_{QS12} = \frac{H_2}{H_1\ \times 24} \times 100\ \%$$

$$where:$$

$$I_{QS12}\ is\ the\ performance\ indicator\ of\ continuity\ of\ supply, in\ percent$$

$$H_1 \text{ is the assessment period, in days}$$

$$H_2 \text{ is the time system is pressurized, in hours}$$

3. Aesthetic aspects of water

Performance indicator:

Water quality complaints [%]

Definition:

$$\frac{\text{number of water quality complaints during the assessment period}}{\text{number of service complaints during the assessment period}} \times 100\ \%$$

Processing rule:

$$I_{QS30} = \frac{F_{18}}{F_{15}} \times 100\ \%$$

$$where:$$

$$I_{QS30} \text{ is the performance indicator of water quality comlaints, in percent}$$

$$F_{15} \text{ is the number of service complaints}$$

$$F_{18} \text{is the number of water complaints}$$

4.

Performance indicator:

Treated water storage capacity [days]

Definition:

$$\text{total capacity of treated water service reservoirs tanks per unit volume of system water input}$$

Processing rule:

$$\frac{\text{total capacity of transmission and distribution service reservoirs tanks } [m^3]}{\text{system input volume during the assessment period } [m^3]} \times \text{assessment period}$$

5.

Performance indicator:

Inefficiency of use of water resources [%]

Definition:

Percentage of water that enters the system and is lost by leakage and overflows up to the point of customer metering.

Processing rule:

$$\frac{real\ losses\ during\ the\ assessment\ period\ [m^3]}{system\ input\ volume\ during\ the\ assessment\ period\ [m^3]} \times 100\ \%$$