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PAPERS

2 **Explanatory factor 'Average Network Age index' (NAX) for mains failures and water losses**
R. Neunteufel, R. Perfler, H. Theuretzbacher-Fritz and J. Kölbl

7 **Challenges in asset management of the water supply and wastewater infrastructure in the Republic of Bulgaria**
V. Nikolov and T. Peitchev

12 **Public-private partnership models for developing water servicing**
D. Stephenson and G. Mokete

15 **A GIS based approach to assess the vulnerability of water distribution systems**
T. Liserra, R. Ugarelli, V. Di Federico and M. Maglionico

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ADB funding for Cambodia water and sanitation project

The Asian Development Bank (ADB) is laying the groundwork for a water and sanitation project that will help improve the health and lives of about 200,000 people living in nine towns in Cambodia, the Lao People's Democratic Republic, and Vietnam.

The towns are situated in economic corridors that have roads linking the six countries of the Greater Mekong Subregion (GMS). A key ADB strategy is to develop the corridors in order to strengthen cross-border ties, expand sustainable economic opportunities, and reduce poverty.

Paul van Klaveren, a Water Supply and Sanitation Specialist with ADB's Southeast Asia Department, said: 'The economic growth of secondary towns in the corridors will lead to higher incomes and improved quality of life for their people.'

A $1.5 million technical assistance is being extended to pave the way for the Mekong water supply and sanitation project. Funding will come from various sources including ADB's Japan Special Fund ($400,000), the Dutch government (a $300,000 grant via the Water Financing Partnership Facility), and the governments concerned.

Delta task force calls for California water rethink

A governor-appointed panel, the Delta Vision Blue Ribbon task force, has reported that California must rethink how it uses, moves and stores water to meet the needs of the state's fast-growing population and protect public health and the environment. The report suggests revisiting the idea of piping water around the Sacramento-San Joaquin Delta and building new dams. The panel also recommended restrictions on development in flood plains, improvements to water quality, and requiring cities and farmers to cut water use.

Indian ADB loan for improved supply, sewerage and management

ADB has approved a $71 million supplementary loan for an urban water supply project in India's Mahya Pradesh state. The project aims to improve the water supply services, sewerage and sanitation services, storm-water drainage, and solid waste management in the largest cities of Madhya Pradesh – Bhopal, Gwalior, Indore, and Jabalpur.

The cities are trade, commerce, and tourism hubs, whose growth potentials are constrained by poor water and sewerage infrastructure systems. DB and India signed a $181 million loan agreement in March 2005 to support the project. However, progress was hampered by slow awarding of contracts, which eventually led to a huge cost overrun due to the rupee appreciation and price increases since the project appraisal in 2003. Other cost increases mean the project cannot be completed as envisaged without more funding.

EIB funds Welsh Water upgrades

The EIB is lending £100 million ($170 million) to Dwr Cymru Welsh Water for a series of water supply and wastewater treatment schemes across Wales. The EIB is supporting the second phase of Welsh Water's 2005-2010 investment programme, which will ensure continued compliance with EU and domestic standards. The EIB-funded projects, which will be undertaken by Welsh Water between 2008 and 2010, will improve living standards for Welsh citizens thanks to essential upgrades in water treatment and improved sewage and wastewater infrastructure. The project will mainly consist of rehabilitation or construction of numerous wastewater treatment schemes and a comprehensive water mains replacement programme across the country.

Philippines project to help meet MDGs

The ADB is helping prepare a project that will improve water supply and sanitation services for urban areas outside Metro Manila, the main urban centre in the Philippines. The Multi-Donor Trust Fund under the Water Financing Partnership Facility (WFPF) will provide a $1.2 million grant to fund project preparation, while the Philippines will allocate $300,000 to complete the funding requirement. The governments of Australia, Austria and Norway contribute to the Multi-Donor Trust Fund. The project is expected to bring the country closer to achieving its Millennium Development Goal (MDG) targets for drinking water and sanitation.

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EDITORIAL

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Explanatory factor 'Average Network Age index' (NAX) for mains failures and water losses

Nowadays various benchmarking studies are aiming to improve the performance in the water supply sectors of many countries. In Austria, significant efforts were spent to determine more than twenty factors influencing the results of performance, which is not common amongst many other projects. Knowing the influencing or explanatory factors enables a better definition of peer groups and so a better assessment of whether some Performance Indicators (PIs) of one utility are in a good or in a poor range.

Concerning mains failures and water losses, the strongest influencing factor besides the structural parameter 'urbanity' was found to be the age of the pipe network. The simple calculation of the average mains age does not consider that different pipe materials have different service lives. The network age index NAX does, and so provides an estimation of how much of the expected service life has elapsed over time. Along with the definition of peer groups, the age index NAX can be used as an explanatory factor for several PIs; to estimate the influence of network age on asset related performance indicators; and in long terms as an estimation whether there is enough rehabilitation and renewal done or not. However it is not recommended to directly derive rehabilitation strategies from age index NAX or to use it as a performance indicator but the NAX can give useful hints whether detailed analyses are to be carried out. R. Neunteufel, R. Perfler, H. Theuretzbacher-Fritz and J. Kölbl in this paper describe why and how the age index NAX was developed and how it is calculated. It includes considerations concerning the used reference ages; possible enhancements and further research; the individual composition of the index value of any utility; and possible applications of the index.

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In recent years, many countries have started benchmarking studies with the aim of improving performance in their water sectors. Starting from 2002, the OVGW (Austrian Association for Gas and Water) benchmarking system was developed by a

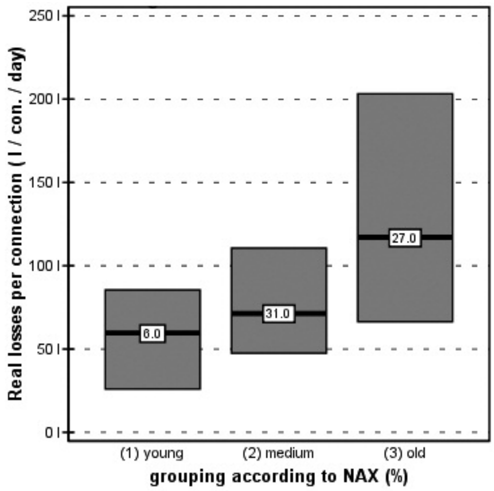

Figure 1
Real losses / connection / day according to network age index

consortium of university institutes and was applied at various Austrian water utilities in a pilot project. The project is predominantly based on the IWA (International Water Association) performance indicator (PI) system (Alegre et al., 2000 and 2006), but was enhanced and adapted to the regional characteristics in Austria. A second large-scale project (stage B) with 72 participants was completed in 2006 (Theuretzbacher-Fritz et al., 2006) representing about 50% of total inhabitants supplied. The water supply sector in Austria is predominantly publicly owned and operated. The benchmarking data gathered were both voluntary and anonymous. A significant effort was made to achieve better comparability across different supply utilities. Aggregated index values on task fulfilment, outsourcing and organization are used as explanatory factors. Grouping utilities according to various influencing factors is crucial to achieve high quality benchmarking. Beside unchangeable structural parameters one of the most important influencing factors found, was the age of the pipe network. Any comparisons of the network age are always influenced by the pipe material mix used by each utility. To have a tool for grouping utilities according their network age and to have an additional explanatory factor for mains failures and water losses, the 'Average Network Age Index' (NAX) was developed by the Austrian project team.

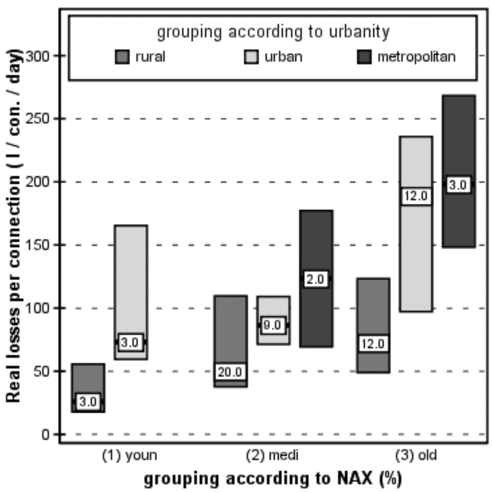

Figure 2
Real losses / connection / day according to network age index and urbanity

Methods

The importance of the assessment of influencing factors

Research on influencing factors has been an important part of the benchmarking project in Austria. The classification was based either on certain context information or on cluster analysis. On the one hand, grouping according to the most important influences enhances the comparability across different supply utilities. On the other hand, differences of median values between different groups quantify the influence of these parameters. To see whether there are differences between certain utilities or not, it was necessary to define peer groups according to the major influencing factors. Otherwise, structurally or somehow other caused influences like network age would possibly hide other findings.

Developement of the Average Network Age index by taking into account service life

The IWA manual on PIs for water supply services (Alegre et al., 2006) suggests the 'average mains age' (# CI53) as context information. The calculation shall be 'based on the age of each main and its length' for the whole system. So the average mains age is a weighted value with the effort of considering the age and length of all mains. However the average mains age does not provide an estimation of how much of the expected service life has elapsed by the time. This is because different pipe materials have different service lives. Similar to different materials, different diameter of each material group show different service lives.

Experience in the Austrian pilot project (stage A) showed that the used context information of 'average mains age' (# CI53) is too general and not appropriate to evaluate the existing mains failure rates and water losses. As an enhancement of the 'average mains age' an index was developed in the Austrian OVGW benchmarking taking into account the service life of different material groups. The average network age index (NAX) is a weighted index, considering the average age and the length-share of each pipe material group. The effort of calculation is similar to the average mains age but including the division of the weighted average age of each material group by the expected service life of each material group. In total the age index NAX takes into account 12 different material groups. For the Austrian benchmarking project in particular these are:

- asbestos cement
- reinforced concrete
- glass-fiber reinforced plastic (GRP)
- cast iron (gray iron) (CI)
- ductile graphite iron 'old' – without protection against corrosion and without cement lining (until mid of the 1970s)
- ductile graphite iron 'new' – with galvanizing against corrosion and cement lining (starting from mid 1970s)
- polyethylene (PE)
- polyvinyl chloride (PVC)
- steel 'old' – without lining (until end of the 1970s)
- steel 'new' – with cement lining and outer PE casing
- renovation (e.g. inlining)
- other pipe materials

To keep the data acquisition simple the differentiation into different pipe diameters was neglected.

The index calculation is shown in formula (1). The age index NAX is therefore displaying the actual share of expected total service life of the total system of water mains.

$$NAX = \Sigma L_i * A_{act,i} / A_{ref,i} \quad [\%]$$

for $i = 1$ to n (1)

L...network length-share of material group [%]
A_{act}...actual average age of material group [years]
A_{ref}...reference age of material group [years]
n...number of material groups

Considerations concerning the reference age

To begin with, some terms and definitions have to be discussed. The service life considered as the reference age is not necessary identical with either the so called physical life of assets or the economic life of assets. The service life also does not mean that no failure or burst must occur during that time.

The service life used as reference age rather represents an empirical value. The reference age for each group of pipe material is the age when the mains typically start to cause major problems and should be replaced. Of course problems are increasing with the age of mains concerning higher mains failure rates and background leakage due to small cracks and failures that could not be found and fixed. Therefore the reference age is to be determined according to a participative approach taking into account the experience of many water suppliers.

The expectable service life is considered to be influenced by many factors. These factors range from national differences like regulatory framework and standardizations concerning production of pipes or construction of mains; to regional differences concerning the surroundings and soil structure or even differences in subsidence and stress caused by static and dynamic loads. To determine these influencing factors widespread research and analysis would be needed. Two ways of determining the reference age were considered:

Regionally different reference ages

Using different reference ages or correction factors for each country or for each region or soil type means that the NAX represents the elapsed share of the service life of a pipe network of a certain region best possible. The advantage is that such individual adapted calculation of NAX will theoretically eliminate all influencing factors and make NAX therefore comparable across any utilities in the world.

The disadvantage of course is the very high effort of calibration of the model in each region or single case. Using many differentiated groups of utilities in order to consider all influencing factors will lead to very small samples and so however hindering a proper calibration or leading to high standard deviations.

Uniformly predefined reference ages

Using uniformly reference ages for one benchmarking project means that the NAX represents the elapsed share of the service life only as an approximation. This is because many region-specific differences and influencing factors are not included.

The advantage is that no complex modelling is necessary and if calculation parameters stay unchanged the NAX is comparable over the time scale. Differentiations concerning country, region or soil type can be done by grouping utilities according to these influencing factors.

The disadvantage is that the NAX value will have an inaccuracy in displaying the elapsed share of the service life across different countries or regions. This is because the region-specific service life can differ from the predefined reference age.

Anyhow, if NAX is utilized as an explanatory factor or for grouping within benchmarking exercises, the inaccuracy is of relative matter and can more or less be neglected. The relative difference in reference ages between long lasting material and less long lasting material was considered to be more important than a very precise absolute value of reference age for each single material group which would change anyway for each country, region or even in single case.

The Austrian benchmarking project uses uniformly predefined reference ages. The expected service lives for the different material groups are based on all: literature values (Fuchs, 2001; DVGW W 401); expert opinions of the Austrian project group; and most important on empirical experiences of several Austrian water utilities. The predefined reference ages are used for the whole Austrian benchmarking project. Sticking to the once defined values without constant updating was considered to be more beneficial to the participants of a benchmarking exercise. Continuity is more important than frequently and precisely updating of the reference ages in order to achieve highly accurate models.

The explicit reference age of each material group is not provided in this paper. This is in order to not influence the discussion within each benchmarking project or each country. A future merger of reference ages used is desirable. In order to achieve a common IWA standard this should happen under the supervision of an IWA specialist group or IWA task group.

Considerations concerning the composition of the index value

Long time operation of a supply network should result in an average network age index of about 50%. Therefore, the index value should be a far-spread composition of very new parts of pipe network, some medium-aged parts and some old parts of network, next to being exchanged provided that failure rates correlate with pipe age. Other compositions can result in index values much lower than 50% (recent built network), around 50% or already higher or even much higher than 50%. Networks with a homogenous relative age may result in a bulk-renewal. A cost-trap might be waiting even if the actual age index NAX is very low at present.

Results and discussion

Possible applications of NAX (Average Network Age index)

Mains failures and water losses are influenced by many factors. In particular these are

- structurally related parameters like urbanity, pipe material and age of the network;
- physically related parameters like static and dynamic pressure head;
- economically related parameters like the type of water resources used and the effort of treatment as the marginal costs of water produced influences the economic impact of leakage.

Any comparisons of the pipe network age or groupings according to the average asset age of different utilities were always influenced by the mix of pipe material used by each utility. To have a tool for grouping utilities according their network age and to have an explanatory factor for failure rates and water losses, the age index NAX should be used. It was found to be one of the most important influencing factors on failure rates and leakage beside the structural parameter 'urbanity'.

One application is to use the age index NAX as an explanatory factor for any performance indicators dealing with failure rates and losses.

Once the influence of the age of assets is eliminated by defining peer

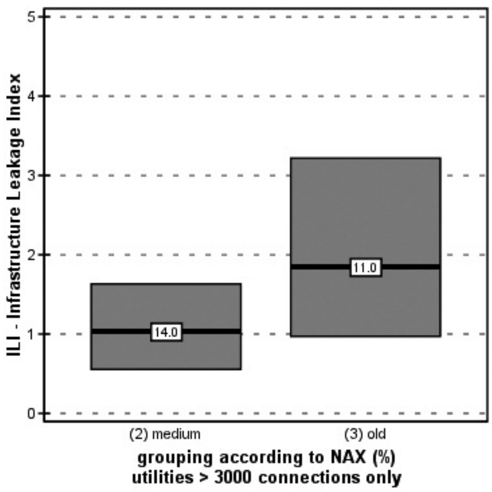

Figure 3
Infrastructure Leakage Index according to network age index

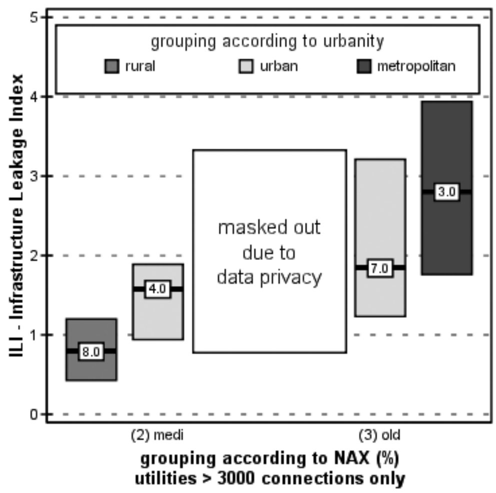

Figure 4
Infrastructure Leakage Index according to network age index and urbanity

groups according to the NAX other influencing factors can be found and quantified. The possibility of sub-grouping according to other influencing factors increases the significance of differences between peer groups.

Another application of the NAX is to quantify the influence of age. This can be determined according to the differences in the median values between the peer groups.

One last application is to monitor the trend of the age index NAX within one utility over the time scale. In longer terms, this could provide estimation whether there is enough rehabilitation and renewal done or not.

However, the NAX should not be used as a performance indicator and thus for the determination of rehabilitation needs or for deriving rehabilitation strategies. But the NAX may be a starting point considering long term development of the age structure of assets. For decisions on replacement or renovation strategies – which part and at what time – failure statistics or even more sophisticated rehabilitation tools should be used. The NAX can only provide a long-term cross-check.

Possible enhancements of the age index NAX

To upgrade the accuracy of the age index a differentiation into different pipe diameters is considered. The effort to acquire data for a weighted age value of several pipe materials times several diameters seems to be much higher than the benefit derived from better accuracy. Therefore the differentiation of diameters has been neglected until now. To keep the data acquisition simple, a certain inaccuracy has to be accepted.

Another issue is non-linear weighting of network age giving higher weights to older parts in order to create awareness to upcoming problems. Considering age distributions of material groups instead of average ages could close the actual gap between the pragmatic calculation of age index NAX and sophisticated rehab software tools. Therefore further research is planned on the cross connection with actual failure rates, water losses and the rate of leakage detection. The upcoming disadvantage with non-linear weighting is that the calculation of age index loses transparency towards the utilities. This might result in decreasing acceptance regarding the obtained results. Therefore only the linear weighting was used by now.

Using NAX in the Austrian benchmarking project – examples

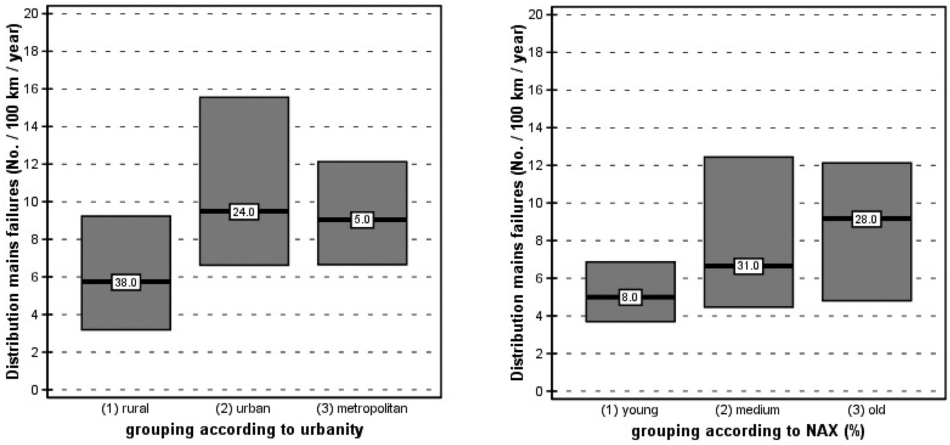

Figure 5
Distribution Mains Failures (transmission mains excepted) according to urbanity (left box) and according to network age index (right box)

In the Austrian project the age index NAX was mainly developed with the purpose to have a tool for grouping utilities according to the age structure of their assets. This was necessary to enhance comparability across different utilities and to define peer groups. Best practices can only be defined within these groups. Utilities with a gap between their performance and the leading performances can derive measures to enhance their practices by learning from partners within their peer group.

The grouping according to NAX values in the Austrian benchmarking is:

- NAX is less than 40% ⟶ young network
- NAX is 40% to 60% ⟶ medium network
- NAX is more than 60% ⟶ old network

Utilities having values close to the threshold values of 40% and 60% are recommended to take into account their neighbouring group as well.

Water losses

Most of the water loss PIs are influenced by all: the urbanity; the network age; the leakage detection and repair; and also by economic considerations with respect to the marginal cost of water produced. For reasons of underground subsidence and stress caused by dynamic loads (traffic) and static loads (buildings) the urbanity is one of the strongest influencing factors on mains failures and on the creation of small leaks unable to be detected and fixed causing the so called background leakage. Another factor, increasing with urbanity, is the number of other infrastructures such as electricity, gas, telecommunication etc. being narrowly laid in the underground and thus influencing each other during construction or rehabilitation. The second most important factor is the age of the network which is displayed as the age index NAX.

Figure 1 shows the PI 'real losses per connection per day'. By the influence of the age index NAX, the median rises from about 60 litres (young) to 130 litres (old) indicating clearly the influence of asset age towards the water losses. The grey box shows 25% and 75% percentiles of the data. The number within the little white box shows the number of utilities displayed in the figure. Minimum and maximum values (whiskers) as well as outliers are generally masked in every figure due to protection of data privacy.

Figure 2 again displays the PI 'real losses per connection per day' but with grouping according to the age index NAX and sub-grouping according to the urbanity. The increase of losses with both increasing urbanity and increasing age of the network becomes very clear. Within this smaller peer groups best practices can be determined and can act as benchmarks to the others within the group.

In combination with the 'level of leakage detection' even more differentiated peer groups can be determined. Of course it should be the goal of every utility to meet a level of high leakage detection to properly fight the water losses. But under one's present situation with the given personnel and the given network age, best practices can be defined and so the resources can be managed in the best way.

Of course sub-grouping sometimes divides the number of participants of a benchmarking exercise into almost too small peer groups. Therefore the Austrian benchmarking data were merged with the data of a partner benchmarking project in Bavaria (Germany) to enlarge the sample by about two (Neunteufel et al., 2007; Kiesl & Schielein 2005; Theuretzbacher-Fritz, 2005). The first results were very promising making the differences between the peer groups more clear and significant but there is no age index like NAX available in the German project yet.

Figure 3 shows the 'ILI' (Infrastructure Leakage Index) according to the age index. As there are only very few utilities with a NAX less than 40% and more than 3000 service connections at the same time, this group (young) is masked out again due to protection of data privacy. Figure 4 displays the ILI with grouping according to the age index and sub-grouping according to the urbanity. This clearly shows the dependence of Infrastructure Leakage Index on both urbanity and age of the network.

Mains failures

Similar to the previously discussed water loss PIs the failure rate PIs are influenced by the parameters urbanity, network age and level of leakage detection as the most important factors.

Figure 5 displays the PI 'distribution mains failures' according to urbanity in the left box and according to network age index in the right box. Figure 5 is revealing that there is no steady increase of bursts with increasing urbanity but a median increase with network age.

Figure 6 displays a clearer tendency for the PI 'distribution mains failures' according to urbanity with sub-groups according to network age index. Still there is the exception that metropolitan utilities have similar or even lower mains failures compared with the urban utilities. As the water losses show a steady increase with urbanity at the same time, the assumption is that metropolitan networks might have higher background leakage than urban utilities due to the above named reasons but not necessarily show higher mains failures. Another assumption is that cracks or bursts in metropolitan cities can not be found as easily due to background noise, resulting in higher leakage and lower mains failures (found and fixed) if it is compared to urban utilities.

Figure 7 displays the 'distribution mains failures' dependent on the network age index and the level of leak detection. This figure reveals of course that younger networks have lower failure rates than older ones and therefore the level of leakage detection has little influence on the bursts found and fixed. Networks with age index 'medium' or 'old' show a clear increase of failures found and fixed with increasing level of leakage detection. This suggests the positive effect of active leakage detection towards reduction of water losses especially within the older networks.

Conclusion

Asset benchmarking has to consider various influencing factors. Concerning mains failures and water losses the strongest influencing factor beside the structural parameter 'urbanity' was found to be the age of the pipe network. The simple calculation of the average mains age does not consider that different pipe materials have different service lives. The age index NAX does. And so it provides an estimation of how much of the expected service life has elapsed by the time.

The age index NAX can be used in different ways:

- as an explanatory factor for PIs dealing with failure rates and water losses;
- as a parameter to define peer groups of utilities in benchmarking projects to enhance comparability across the utilities and find best practices within related situations;
- to estimate the influence of network age on asset related performance indicators;
- as an estimation whether there is enough rehabilitation and renewal done or not in longer terms.

However it is not recommended to directly derive rehabilitation strategies from age index NAX. But PI results which are evaluated with respect to the age index NAX can give useful hints whether detailed analyses with rehabilitation tools are to be carried out.

Together with other influencing factors the age index NAX is an additional tool that enables a better definition of peer groups and so a better estimation of whether some performance indicators of one utility are in a good or poor range. Concerning water losses and mains failures this results in either having a need to change asset management or to stick to the present procedures. ●

Acknowledgements

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References

Alegre H., Hirner W., Baptista J.M. and R. Parena (2000): Performance Indicators for Water Supply Services. Manual of Best Practice, IWA Publishing, London, UK.

Alegre H., J.M. Baptista, E. Cabrera Jr, F. Cubillo, P. Duarte, W. Hirner, W. Merkel, R. Parena (2006): Performance Indicators for Water Supply Services - Second Edition. Manual of Best Practice, IWA Publishing, London, UK. ISBN: 1843390515

DVGW Hinweis W 401 (1997):Entscheidungshilfen für die Rehabilitation von Wasserrohrnetzen

Fuchs D. (2001): Decision Support Systeme für Rehabilitationsplanung von Wasserrohrnetzen. Schriftenreihe zur Wasserwirtschaft, band 35, Technische Universität Graz [german]

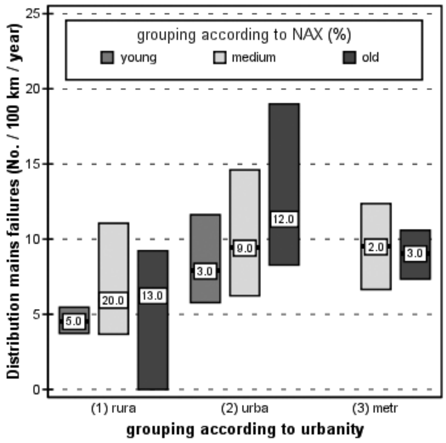

Figure 6 Distribution mains failures (transmission mains excepted) according to urbanity with sub-grouping according to network age index

Kiesl, H. & J. Schielein (2005): Effizienz- und Qualitätsuntersuchung der kommunalen Wasserversorgung in Bayern (EffWB) 2004. – Final Public Report on Bavarian project 2004/05) [german]

Neunteufel R., R. Perfler, H. Theuretzbacher-Fritz, J. Kölbl (2007): Water Supply Benchmarking – A Cross-Border Comparison of Outcomes an Benefits in Austria and Southern Germany, IWA specialist conference on efficient use and management of urban water supply 2007, 20.-23. May 2007, Jeju Island, Korea

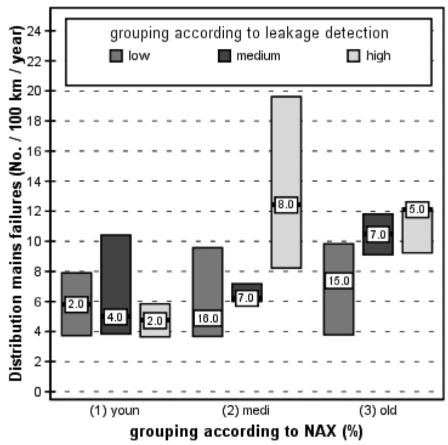

Figure 7 Distribution mains failures (transmission mains excepted) according to network age index with sub-grouping according level of leakage detection

Theuretzbacher-Fritz, H., Schielein, J., Kiesl, H., Kölbl, J., Neunteufel, R. and Perfler, R. 2005. Trans-National Water Supply Benchmarking: The Cross-Border Co-operation of The Bavarian EffWB Project and The Austrian OVGW Project. - Water Science & Technology, Water Supply 6 (2005), p. 273-280.

Theuretzbacher-Fritz H., Neunteufel R., Kölbl J., Perfler R., Unterwainig M. and R. Krendelsberger (2006): Benchmarking und Best Practices in der österreichischen Wasserversorgung – Stufe B - Final Report on Austrian project 2005/06, Graz-Vienna-Wiener Neustadt, Austria [german]; www.trinkwasserbenchmarking.at

Paper presented at LESAM 2007 – 2nd Leading Edge Conference on Strategic Asset Management

Challenges in asset management of the water supply and wastewater infrastructure in the Republic of Bulgaria

V. Nikolov and T. Peitchev aim in this paper to make critical professional assessment of the historical and current management of the WSW sector in Bulgaria, and to recommend variants of an optimal management structure.

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Water supply in Bulgaria is at a comparatively good level; this is confirmed by the following facts – the extremely high level of central water supply for the population in the country (98.8%), the large scale water supply systems, and the highly qualified engineers and specialists in the field of water supply and wastewater (WSW). Nevertheless, there are a lot of serious problems in the water sector, accumulated since 1989, when the change of the political and economic systems began, accompanied by an economic crisis. These changes affected the water sector as well, and the WSW sector in particular.

The aim of this paper is to make a professional assessment of the management models implemented and carried into practice in the country, to compare them with those in the EU and other industrialised countries, as well as with the common requirements and regulations of EU and the expected challenges in the next 10-15 years. As a result of this analysis variants of optimal management models in the WSW sector are recommended.

Management of the WSW sector in Bulgaria

The beginning of the centralized water supply in Bulgaria was in 1897, when the *Act on Public Works in Settlements* was adopted. Since then, the WSW sector has gone through different stages of management, the most characteristic of which are the following:

1966 – 1989

The WSW sector was managed by the Ministry of Construction and Architecture, successor of which concerning WSW activities is the present Ministry of Regional Development and Public Works (MRDPW). There were several main organisations functioning in the water field, as:

- The Department of Water Supply and Sewerage in the Faculty of Hydrotechnics at the Higher Institute for Architecture and Civil Engineering (renamed to University of Architecture, Civil Engineering and Geodesy in 1995). The Faculty and the Department train civil engineers in the field of water supply and wastewater disposal.
- The Research Institute for WSW, established in 1960. The main objectives and activities of the Institute were scientific, scientific/applied and technological/research; gathering of information and data; drafting regulations, strategies, methodologies, instructions, etc. in the field of water supply, sewerage, water and wastewater treatment.
- The National Design Institute 'Vodokanalproekt' with main functions to investigate, design and construct the water intake installations and equipment for all projects of national and regional significance. This Institute designed all WSW systems, water and wastewater treatment plants and pumping stations in the country.
- The State Directorate 'WSW', which performed the activities of investment and exploitation of all WSW systems in the country, except those in Sofia. The governance was performed by a General Director (appointed by the MRDPW) and an Economic Council (with representatives from all regional branches). The State Company had regional branches in all of the 27 administrative regions of the country. The ownership of all WSW systems and equipment was 100% public (state).
- The WSW Company for Sofia, which performed the activities of investment and exploitation of the city's WSW system, delivering drinking water and providing wastewater services. The assets of the Sofia WSW Company were 100% public (municipal) property.

During this period the water price was equal for the whole country and was determined by the Government. The assets of all WSW systems were public property and the financial resources for investment projects were provided and ensured by the state. This period can be named 'the golden period' of the Bulgarian water supply and wastewater sector as there were built WSW systems at a large scale and 98.8% of the population in the country was provided by centralised water supply – a level that has not yet been reached by many European countries. Some of the systems are situated on a territory comprising dozens of municipalities from several administrative regions, and the water source is at one of them. During this period, many and various studies and scientific investigations were carried out and highly qualified engineers and technicians were educated and trained.

The experience in Bulgaria till 1989 showed that the existing structure of WSW Sector of that time – with one municipal WSW Company for the capital city Sofia and one state WSW Company for the rest of the country, was the best among all the models existed in the water sector through the years. The advantages of this model are the following:

- Unified national policy in WSW Sector is carried out and implemented;
- The price of water is equal for the whole country; it allows the application of the principles of social solidarity and equality;
- Centralised scientific/applied and technological/research activities were carried out as well as information services, methodical guidance

of all the chemical-bacteriological laboratories; drafts of norms and regulations were drawn up; international cooperation and transfer of the positive foreign experience and good practices and education and training of managers and skilled personnel were accomplished; financing of large-scale investment projects, etc.

1989 – 1995

Restructuring of the WSW sector began following the proposal of the World Bank, and the so-called 'water loan' was signed. As a result, the State WSW Company was closed down in 1989 and a number of independent companies were set up – 29 state-owned and 14 municipal-owned. The closing down of the national WSW company was the biggest mistake in the water sector; the current situation is a consequence of this step.

1995 – 2006

- Out of the existing 29 state-owned WSW companies, 16 are transformed into mixed state-municipal companies with 51:49 ratio of shares; the state committed gratuitously some of its property to the municipalities. The shares between the municipalities are distributed proportionally to the number of their population without taking into consideration the real value of the WSW infrastructure. According to the instructions of the World Bank, the aim of the restructuring of the WSW Sector is that the state has to assign in the future the remaining 51% of its property to the municipalities. Fortunately, this second stage was not realized.
- 22 municipal WSW companies are set up with 100% municipal ownership of assets.
- 1999 - the ECO AQUA TECH Institute (the former Research Institute for WSW) is shut down;
- 2000 - Vodokanalingenering (former National Design Institute 'Vodokanalproekt') has become 100% private but its activity remains symbolical.
- 2000 - A Joint Stock Company (AD) 'Sofiyska Voda' is created between the Sofia Municipality, the UK company 'International Waters', the American company Behtel and the Italian company Edison. The WSW services in the capital city of Sofia are given under 25-year concession contract to 'Sofiyska Voda'. The ratio of assets between the municipality and the concessionaire is 23%:77%.

  Nowadays, the foreign stockholders in 'Sofiyska Voda' are the UK Company United Utilities and the European Bank for Reconstruction and Development (77% of the assets), buying out the shares from the previous concessionaires.

  The Sofia Concession turned out to be a major problem for the capital; it remains on the top list of the news. In June 2006 the Parliamentary Commission against Corruption ascertained a corruption practice in the concession contract between Sofia Municipality and 'Sofiyska Voda' AD.
- February 2005 - The Water Supply and Wastewater Services Regulation Act was adopted; according to the Act the WSW services became an obligation of the existing State Energy Regulatory Commission, which added 'Water' in its name and became State Energy and Water Regulatory Commission (SEWRC). The State commission started its real functioning at the end of 2006. The standpoint of the Bulgarian Water Association on the Water Supply and Wastewater Services Regulation Act has been negative from the very beginning, because:
  - The need of such state regulatory body is not proved, as all water companies in the country, except one, are public.
  - There is no EU country having a joint regulatory body for energy and water services.
  - The members of the SEWRC were appointed contrary to the law (without having the necessary qualifications and length of service in the WSW field).

By its form of government according to the Commercial Act, the water companies are: EOOD (Single Person Limited Liability Company), EAD (Single Person Joint Stock Company), OOD (Limited Liability Company) and AD (Joint Stock Company). With the exception of the region of Sofia city, all other companies have public management (state, municipal or mixed – state-municipal).

The status of the water companies and their management by June 2007 is the following:

- Total number – 60
- 100% State companies – 11 EOOD and 1 EAD
- 100% municipal – 27 EOOD
- State-municipal with 51:49 ratio of shares – 16 OOD and 1 AD
- Private concession – 1 AD (Sofia City)
- Others – 3

There are several cases where parts of WSW systems (water-intakes installations, pump stations, treatment plant, etc.) providing services to urban areas have become private. This happened during the processes of privatisation of the industrial enterprises as these parts of the WSW systems were in their assets.

The state policy in water sector is laid down and conducted by the National Assembly, Council of Ministers and the Ministry of Regional Development and Public Works. The governing bodies of the water companies (Managers/Directors and governing councils) are appointed and dismissed by the Minister or, in the case of municipal companies, by the respective municipal councils.

New WSW projects, as well as the rehabilitation and renovation of the existing systems are financed mainly from the state and municipal budgets, from European funds (PHARE, ISPA and SAPARD), bank loans and resources of water companies themselves. The financial resources from the European funds are coordinated by:

- MRDPW – for WSW projects and systems in the country;
- Ministry of Environment and Water (MoEW) – for inlet sewers and wastewater treatment plants;

When regulating the organisation and management of water services, it should be taken into account that the sector has specific characteristics, which are not valid for other industries and services, namely:

- WSW is an industry (water industry) which produces and delivers water to consumers for drinking, industrial and other needs, whereupon receives, disposes of, and treats wastewater to a degree which allows discharging into water intakes;
- 'Water' as a commodity is very specific and therefore it is a 'special commodity';
- The water industry relies on a secured natural raw material (the national water resources) and naturally secured monopoly market;
- WSW provides public services of natural monopoly character;
- Drinking water is the only product of vital social and sanitary importance which can not be imported through transport vehicles;
- The WSW activity comprises the manufacturing process organisation and delivery of water to consumers as well as wastewater disposal. Therefore, the public authorities' role for the organisation and control of the WSW services should be their obligation by law. BWA insists this obligation to be included in a new WSW Act.

Currently, **the main problems** in the

WSW sector are the following:

- The water sector is not a state priority;
- The ownership and management of the WSW systems are still not well regulated;
- Water sector is governed and controlled by three state bodies – MRDPW, MoEW and SEWRC;
- The rights, obligations and responsibilities of the public authorities (state), water operators, water consumers and branch WSW non-governmental organisations (NGOs) are still not completely and precisely regulated;
- There are elements of WSW systems in the assets of privatised industrial enterprises;
- Due to not quite clear property issues there are serious problems and difficulties in putting into operation of already built WSW facilities;
- The number of the existing WSW companies in the country is too high – more than 60. The companies are regional (state-owned), municipal, mixed (state-municipal) and private; they possess WSW assets and provide WSW services;
- A significant percentage of WSW systems are old and technically out of order and there is an urgent need for rehabilitation or even complete reconstruction; nevertheless no real actions and steps are undertaken and the water losses unjustifiably have reached extremely high levels;
- The number of settlements under water rationing – permanent or seasonal, is considerably high;
- Insufficient sewerage rate in settlements and low percentage of treated wastewater;
- There is no national WSW centre to provide scientific, technological, methodological and strategic management services to the water sector.

In the EU countries, there is a great variety in the forms of ownership and in the management models of the WSW systems. Therefore, each country decides on its own how to proceed with these issues. The situation is similar in other industrialized countries in the world.

Main conclusions related to management of WSW sector in Bulgaria

As a result of the analysis about the positive experience in the water sector, the following is deemed expedient for Bulgaria:

- WSW systems should remain public.
- The management of WSW systems should remain public, through public operators.
- One state body should perform the governance of the water sector.
- Water supply and sewerage are two components of one and the same process, from water sources to the wastewater discharge into the water intakes. Therefore the complex and joint management of WSW services should remain as it is now – performed by one and the same water operator/company.
- WSW services should be delivered to the society directly by the water operators/companies, without intermediaries.
- It is necessary a national WSW center to be established to provide scientific/applied, technological, and strategic management services to the water sector.
- It is necessary the issues regarding the unified management of the WSW sector to be carefully considered (except Sofia) as well as the equal price of water in the whole country. It would allow the application of the humane principles of social solidarity and social justice.
- Taking into consideration the bad experience in Sofia, the concession as a management model should not be implemented.

Main challenges in WSW sector

According to the authors, the main challenges in the WSW sector in Bulgaria are the following:

- Inadequate regulatory provisions for the sector (legislation and regulations), including the infrastructure ownership and management;
- The price of water and the quality of WSW services;
- The quality of the drinking water;
- High levels of water losses in the water networks;
- Rehabilitation and modernisation of the existing water treatment plants and construction of new ones;
- Necessity of laying of thousands kilometres of sewers for settlements and hundreds of wastewater treatment plants;
- Protection of the national water resources from pollution and exhaustion;
- Providing the necessary financial resources for rehabilitation and construction of new water supply systems and facilities;
- Education, training and qualification of managers, engineers, experts and workers for design, operation and management of WSW systems, including treatment plants.

Considering the good Bulgarian traditions in water field and its current unsatisfactory condition; the great potential of the country, still insufficiently used; the achievements of water management worldwide, the EU requirements; the territory size and population of the country; the tradition people to drink water from the tap; the **main challenge** in WSW sector is its insufficient regulation. Solving this main challenge needs good political will and undertaking the following urgent steps:

- Adoption of a new **Water Act.** It has to regulate the ownership of water as well as the basic principles of protection, rational use and management of water resources; to implement the essential part of the European Water Framework Directive without considering the issues related to the ownership of the water systems and facilities. Those issues should remain to be considered in more specific acts; WSW Act is one of them.
- Adoption of **Water Supply and Wastewater Act.** This act is the key for solving the problems in water sector because it should regulate the rights and obligations of all stakeholders. WSW Act should define clearly and precisely the following basic issues:

1 Management of the water sector by one state body (Executive WSW Agency, for example).
2 Public property of WSW systems and facilities.
3 The access to drinking water should be declared an irrevocable human right.
4 All facilities owned by private juridical and physical persons should be reversed in public assets.
5 Admissible models for management of WSW systems and services; priority should be given to public management. Concession must be left as a last option.
6 Regulation of the water quality and the price of WSW services should be performed by independent public-state authority.
7 The rights, obligations and responsibilities of public authorities; water operators/companies; water consumers and branch NGOs.
8 Sources for financing of investment projects (if appropriate conditions exist, the WSW sector could be self-financing).
9 Establishment of National WSW Center, providing scientific/applied, technological, informational and methodological services to the sector, as well as preparing of legislative documents, strategies, standards, regulations, instructions, etc.; transfer of foreign positive experience and good practice; qualification and training of managers and workers.
10 Education, qualification and training of managing and working personnel of the public operators.

11 To point at the basic sub-normative documents (regulations, standards, norms, etc.), regulating the design, construction and operation of the WSW systems and facilities.

The above mentioned challenges could be successfully solved, if adequate political decisions are adopted. The financial challenges are also of significant importance, but they are mainly due to unsettled issues and problems with property and WSW management. If the water sector becomes part of the state priorities, we are confident that the professionalism of the Bulgarian experts and specialists in water field will guarantee the delivery of high-quality water services according to European criteria.

Models of WSW sector management

Two main preconditions are necessary in order to achieve a high level of WSW services:

- Water sector has to become a state priority;
- A specific WSW Act should regulate the water sector.

There is a common understanding between the political parties and the branch WSW organisations in Bulgaria that the property of the water systems should remain public. Differences appear when passing to the next question – which systems or parts of them should be state property and which should be municipal property. This question does not presume a single answer, and a reasonable compromise should be sought. Several essential factors, specific for Bulgaria, are influential here:

- Some of the existing water supply systems cover the territory of dozens of settlements belonging to different municipalities and regions;
- There are urban areas whose waste water treatment plants are located on a territory belonging to another municipality;
- There are small and poor municipalities, which, alone, do not have the capacity to develop and maintain WSW systems on their territory. It is necessary for them the principle of social solidarity to be applied, which is possible only for a large enough region with economically strong municipalities;
- In certain occasions, a component of the WSW system (water source, pump station, treatment plant, etc.) is included in the capital of privatised enterprises. Law should correct this failure in the privatisation process.

The form of ownership has a decisive importance for water service efficiency. The practice since 1989 indicates that almost all newly established municipal companies worsened sharply the technical condition of the systems and the quality of water services. Nowadays, the municipalities are not ready to manage independently this activity.

Forms of ownership and asset management models

We consider that in respect of the most important issue – forms of ownership of the WSW assets, the following variants are possible, ranked according to their positive aspects:

Variant 1 - Public state ownership of all WSW systems and facilities, except those of Sofia municipality

Option 1.1 - An Executive Agency is established (or another governmental body) to perform investment and exploitation activities of all public WSW systems, which assets become state property.

The Agency should have branches in all 27 administrative regions of the country. It is reasonable and expedient that a National WSW Centre to be also established under the Agency's governance.

Advantages:

- Central management of the sector;
- Implementation of unified, nationally responsible policy in water sector;
- The regional management structure is preserved;
- Application of objective criteria and equality in using the WSW systems and distribution of water among the municipalities and settlements, especially important in case of water shortage;
- The state is engaged with reconstruction, modernisation, enlargement and maintenance of the WSW systems. This is of great importance when there is a necessity of construction of large and extremely expensive facilities, as dams, treatment plants, etc.;
- This form of ownership guarantees normal WSW services to little and financially poor municipalities;
- An opportunity to set both unified and differentiated prices of WSW services in the individual regional companies, depending on the specific conditions;
- The technological completeness of the WSW systems is preserved.

Disadvantages:

- A legislative act should be adopted to reinstate the public state ownership of the WSW assets, already transferred to some municipalities.

Option 1.2 - Four public WSW companies are set up on a basin principle

Their operational territories are identical to the River Basin Directorates for water resources management.

Advantages:

- The advantages of this variant are similar to those of the first one; however, four separate and independent WSW companies have to be established and respectively, as in the first variant, with regional WSW branches;
- Conduction of unified policy in the
- WSW sector, complying with the requirements of the basin-type water management.

Disadvantages:

- A legislative act should be adopted to reinstate the public state owner ship of the WSW assets, already given to some municipalities;
- Four, instead on one, public WSW companies; this inevitably will lead up to necessity of more personnel, administrative and financial expenses;
- Necessity of national co-ordination body/centre;
- Necessity of national independent WSW Centre.

Variant 2 - Public municipal property of all WSW systems and facilities

Option 2.1 - Establishment of association of municipalities for WSW systems operation in the four Basin Directorates

Advantages:

- Four WSW companies will be established, capable to ensure high level of WSW services for all settlements in their territories;
- Carrying out one centralised policy in the water sector in conformity with the requirements of the basin management of water;
- The local authorities are strongly engaged with WSW problems and responsible for their solutions towards their own population;
- Best possibilities for benefits from the different funds for financing the WSW sector;
- Preservation of the technological management in common and the territorial integrity of the big WSW systems, functioning and providing services for settlements belonging to different municipalities and administrative districts;
- There is no necessity to reinstate the public state ownership of the WSW assets, already given to some municipalities.

Disadvantages:

- Difficulties in partitioning the WSW property between the municipalities

when an WSW company operates and provides services to areas, belonging to more than one municipality;
- Possibility of settlements from one and the same municipality but belonging to different basin areas, to be water supplied by different WSW companies;
- There is a need to adopt legislative documents (acts, procedures, etc.) regulating the mandatory establishment of association of the municipalities in the framework of the Basin Directorates.
- Difficulties in coordination between municipalities.

Option 2.2 - Mandatory establishment of association of municipalities in the framework of the existing administrative districts of the country, as well as mandatory establishment of association of those areas for which water is supplied by joint WSW systems

This variant presumes preservation of the current regional structure of the WSW companies and establishment of an association of those having joint water supply systems.

Advantages:
- The current regional structure of WSW systems and management traditions are kept.
- Preservation of the unified techno logical management and the territorial entirety of the big WSW systems functioning and providing services to settlements belonging to different municipalities and administrative districts;
- Best possibilities for benefits from the different funds for financing the WSW sector;
- The local authorities are strongly engaged with WSW problems and responsible for their solutions towards their own population;
- Establishment of regional WSW companies with enough financial resources and personnel, capable to provide sufficient levels of water supply to settlements both from big and small municipalities;
- Application of objective criteria and standards; equality in water distribution and delivering WSW services between the different municipalities;

Disadvantages:
- Necessity of legislative document for mandatory establishment of an Association of municipalities belonging to the one and the same administrative districts and if necessary – establishment of an Association of municipalities from different regions;
- Difficulties in partition the WSW property between the municipalities when a WSW company operates and provides services to areas, belonging to more than one municipality;
- Necessity of national co-ordination body/centre for WSW activities.

Variant 3 - Public state or public municipal property of whole or parts of WSW systems

The essence of this variant is the following:
- WSW systems and installations or parts of the systems, operating and delivering services to more than one municipality, are public state property;
- Water supply and sewerage networks in the settlements, wastewater treatment plants, as well as those parts of WSW systems, which provide services to one municipality; all situated on the municipality's territory, are public municipal property.

The Municipal council will set the model of management of the public municipal property. The respective state authority/body will set the management model of the state WSW property. The state WSW company/operator will deliver water to the appropriate settlement's site (reservoir, etc.); the price of this service will be determined by the Council of Ministers.

Advantages:
One WSW Company will operate and deliver services to a considerably large territory of the country; this model has all the advantages of the centralised management mentioned above.

Disadvantages:
- WSW systems with public state ownership will be technologically separated from each other because they will be situated on different territories of the country;
- There is a necessity of many regional branches of the state WSW Company to operate and maintain the individual WSW systems;
- Many municipal companies will be established, some of them large enough and capable to function successfully, but also a big number of medial and small ones, with limited resources (financial, technological and personnel) to reconstruct, modernise and enlarge their WSW systems;
- The biggest and substantial municipal companies can be given to concession, but the smaller will remain as a burden of the state, i.e. to the whole society;
- There will be municipalities receiving water and other services by someone else's WSW company without any effort, and their only obligations will be to maintain and enlarge their own territorial WSW infrastructure; and at the same time, there will be other municipalities, with much more responsibilities than that; they will have to maintain the external WSW networks and installations and also to provide the financial resources. A strong conflict if interests and inequality among municipalities could arise as a result of this, with all the consequences;
- This variant presumes possible and desirable forms of joint associations between municipalities (based on the principle 'large – small' or 'rich – poor'); however it is too difficult to be accomplished.
- Necessity of national co-ordination body/centre.

We believe that with respect to the most important issue – the form of ownership of the WSW assets – **variant 1** (options 1.1 and 1.2 respectively) has the most serious organisational, technical, technological, operational and social advantages out of all recommended variants; however it requires legislative actions to reinstate the public state ownership of the WSW assets, already given to some municipalities. In any case, the strategy should be aimed at a considerable reduction of the number of the WSW companies.

Conclusions
- The WSW sector is a water industry, which produces and delivers water services to the society with natural monopoly character and strong vital social and sanitary importance.
- The Bulgarian tradition – water supply and wastewater services to be concentrated in one company – should continue, without intermediaries.
- It is expedient for the conditions in Bulgaria WSW infrastructure to remain public.
- The most suitable model for management of WSW companies is the 'delegated public management'.
- It is expedient one state body to be established for coordination of the WSW activities in the country.
- It is necessary a national WSW centre to be established under the guidance of the coordinating state body to provide scientific/applied, technological, informational, legislative, strategic and methodological services to the sector.
- The water sector urgently needs Water Supply and Wastewater Act. ●

Paper presented at LESAM 2007 – 2nd Leading Edge Conference on Strategic Asset Management

Public-private partnership models for developing water servicing

D. Stephenson and G. Mokete discuss the necessity for private partnerships in financing water services and models are presented to discuss the role of different agencies in development. The extent of investment particularly in developing countries is lamented and ways of speeding the process investigated.

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Introduction

Private participants in the water industry are many, but those venturing into financing of water services in developing counties are few, and of those, some have burnt their fingers. There are high risks in developing countries, associated with construction, management and debt collection. The demographic situation can be vastly different to that in developed countries, to the extent that immigrants into the services can flounder.

The international market for water is some US$400 billion per year. This may be compared to the market for electrical energy of US$1000 billion a year. And the water market figure is only for urban water consumption, i.e. residential, commercial and industrial, but it includes potable water supply and wastewater collection and treatment.

The private water market is largely in Western Europe (30%), followed by Asia (28%), North America (25%) and in decreasing order, Eastern Europe (5%), Latin America, Oceania, and Africa. The annual growth in the water market is some 8-10% a year, made up largely from developing countries. Water is becoming an increasingly valuable commodity due to reducing relative resources, pollution, further sources and increasing costs of storage (Dinar et al, 1997).

Most public water supply companies have been protected by governments and are inefficient and not customer orientated. There is a large loss rate, i.e. about 30% of water supplied is unaccounted-for. This is indicative of neglect. And many people still remain unserviced. Although there are large international companies able to operate water supply companies, they are still met with a high level of distrust in some cases. It should be borne in mind that the water supply industry is capital intensive and the payback time is long, i.e. there are no rapid profits to be made.

Most new investment is required where people are least able to pay. For many of those, water is seen as a right and not as something for which they have to pay or an economic good. The result is that many private companies shun the operation in those environments. So many water companies end up in the hands of incompetent or nontransparent government appointed organizations.

Investment needs

The amount of money required to be invested in water supply and water services over ten years is as follows: In Asia, some US$280 billion is required, in Latin America, US$220 billion, in Africa US$80 billion, in the Middle East US$45 billion, in Eastern Europe US$40 billion, and in North America and Western Europe US$35 billion.

Some obvious facts indicate most water companies are under-performing.

The percentage of the population not connected to a potable water supply scheme ranges from 58% in Indonesia, down to 20% in South America, while in Western Europe and North America practically all people (over 95%) have direct access to potable water.

The percentage of the water supply systems operated by private companies is still small. Of the total of the world population of 6 billion, only about 5% are served by private companies. Of this 290 million people, 126 million are in Europe, 72 million in Asia and Oceania, 48 million in North America, 21 million in South America, and 22 million in other countries.

Although it may be said that the privatization forces are only starting to push, the fact is that they may have burnt their fingers or are reluctant to embark on high-risk ventures, particularly in the developing world. The models for private ownership are only beginning to emerge and become attractive in some instances. Whereas the past has seen public ownership models, including management contracts, lease and concessions, the change is now to private ownership models or private consultancies, and these are typified by build-own-operate-transfer (BOOT), joint ownership, i.e. public-private partnership, and decreasing the outright sales.

The waves of privatisation in the United Kingdom have been watched by the world. The first wave of privatisation starting in 1973 saw approximately two thousand companies involved in the water industry. The second wave of privatisation after 1989 narrowed the focus to 40 companies, i.e. a concentration compared with the earlier diversification. The creation of a high level of regulation in the United Kingdom has enabled benchmarks to be provided and individual performances to be reviewed, while at the same time cost effectively improving the water companies and their profitability, or at least levelling off and reducing the risk. The past models and the trials and failures of previous companies have narrowed down the uncertainty and the scope for opening up unknown management methods.

The learning curve in the UK has benefited many later entrants. Asset management, asset registers, regulators and benchmarking are some of the technologies springing from the process.

Whereas the big companies in the market at present include Suez, Saur, Thames, Severn, Anglian and Vivendi, there may be amalgamations particularly in view of newer technologies and financial requirements. The amalgamation with the energy business may also bring other players into the water services market (see Roth, 1987).

Appropriate Technology

It is recognized that conventional western designs are not necessarily the most practical in developing areas. The following additional factors should be borne in mind in water and sanitation for developing areas:

- Capacity building is required at the lowest level where communities are unaware of management methods and ways of financing projects.
- Technical and management skills are absent in poorer communities and capacity building is therefore essential to ensure technical sustainability, i.e. maintenance and expansion.
- Lack of funding may require different forms of local input such as cheap labour or revenue collection or even different ways of distributing the water. Piped water supply, for example, is not always a solution and it is difficult to monitor and collect rates. Container systems with pre-payments may therefore be in fact a more viable solution (McLeod, 1997). In the end technology and modus operandus should be demand driven, not imposed, which is what funding should consider.

It is in the inter-relationship between sanitation and water supply however that new ideas are sought. It is recognized that most water in westernized households is used for sanitation and ablutions. Alternative systems should not be discouraged, particularly in rural areas where piped water supplies may not be the answer. The only advantage of collective wastewater treatment is that water from sanitation systems is collected communally and treated to a reasonable standard and may therefore be usable. However, if the water used for transport of waste is not required, the water consumption is much less. Thus the viability of alternative sanitation systems needs to be considered together with the water demand.

Water management on a local and catchment scale needs to be brought into practice. Frequently, much of the available water is not usable because of water pollution or because of poor distribution in time and space. Water storage in reservoirs to solve the time management of water is not always a solution because it increases evaporation losses. Water management

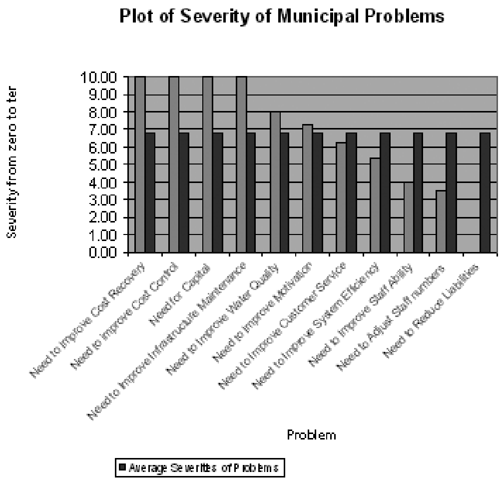


Figure 1
Illustration of importance of various factors in deciding level of privatization

in space by means of pipelines is expensive and not sustainable for poorer communities.

Another reason for encouraging local participation is the acceptability of risk. Whereas large international funders may shy away from funding projects which are risky in the way of inability to supply or collect payment for water, communities may be prepared to suffer the consequences of risk if it makes the water more affordable, The risk could be running dry of a source, uncontained pollution or inability to pay. These will be managed in different ways by people with different resources and abilities. For example, alternate sources of water may be further away, but the value of time is different to everyone and to some the time in collecting water further away may be affordable. Occasional pollution problems may be overcome by disinfecting or boiling, and financial cash shortages may be met by labour input.

It is seen that the way of development will be at all levels of supply, ranging from the smaller community systems discussed above to regional and national supply projects. A proper governmental structure linking the systems is needed to ensure training and promotion of people through the system. In fact, it is envisaged that once a system is established it could serve as an upgradeable model for developing countries.

The use of the water should go hand in hand with planning and research because the system could be rendered unsustainable either from overuse or from overestimation of the resources available. Therefore, proper databases need to be built up and alternatives considered in balancing supply and demand. Thus a water research centre is envisaged covering technical, management and funding problems. Technical problems which could be addressed include;

- Designs using local facilities and workforce to increase local input and ability to pay.
- Alternative water sources including hybrids to reduce risk.
- Alternative transport including animal drawn.
- Alternative energy sources.
- Water quality and disinfection.
- Standards relating to quality, quantity, pressure and reliability.

Social studies should be made to develop appropriate solutions for design and implementation of water supply and sanitation facilities which are at the correct level for seeking funding, and acceptable to the public. Customs, prejudices and importance should be addressed.

Water conservation is of prime importance in arid areas. Hence awareness of water cost, ways of minimizing use and alternatives such as rainwater harvesting must be explained via awareness campaigns. The tariff for water should reflect its value even if only on marginal use. So multi-departmental co-operation is needed to ensure the correct billing tariffs. For example schools waste water as they are not responsible for paying the monthly accounts. Governmental education is therefore also needed and guidelines and seminars should be organized.

Public-private partnership models

There are a number of role models which have been attempted in drawing the private sector and its money into the public water arena, including;

- Full privatisation
- Concession
- Lease contract
- Management contract
- Service contract
- Corporatisation
- Public-public partnerships
- BOOT and build-operate-transfer (BOT) projects
- Municipal debt issuance
- Private consultants

The type of partnership depends on the needs of the sector and the desire for net profit by the company.

Needs which can be met by private companies:

- Cost recovery
- Cost control
- Liability and exposure minimization
- Capital input
- Maintenance
- System optimization
- Staff and asset minimization
- Quality of water, pressure, reliability
- Staff motivation and ability
- Customer service, accessibility

Private sector participation has become an essential way of financially assisting in the water service delivery train. Older models of privatization included purchase of the water company, lease, and BOT. These models have metamorphosed over years but viable solutions have not been found for developing countries. Partnerships involving risk sharing and community participation are going to be needed. The ability of communities to pay true costs must be balanced against service standards. Alternatives to cash payments for services in initial years may be work input, responsibility sharing and alternative technical solutions. But capacity building should be arranged in parallel to ensure future payments.

Current public funding is insufficient to meet demands in Africa as a whole. That is not only to catch up on backlogs, but also to sustain water services industry growth. Donations are also insufficient to go beyond token attempts to redress the situation. So private investment is the solution and the opportunity for leverage is a good way forward. The order of funds required to provide basic potable water to unserviced communities in Africa as a whole are nearly €50 billion ($78 million) . This shows the solution is not possible by simple donations and self funding by increasing economic turnover is the most possible scenario.

Some of the issues which need to be addressed are;

- Level of risk in supply level, viz reliability of source and quality, and the appropriate level bearing in mind alternatives open to poorer communities. Reliability can add to the capital cost, for example bigger reservoirs.
- Internal generation of wealth. Closing the expenditure cycle/chain is a way of generating wealth to enable people to pay for water services. Small manufacturing, construction and maintenance teams need be established.
- Sources of funding, overseas and in Africa, including developing own funds. Own funding may be in the form of labour rather than capital, necessitating human asset management.

Obtaining the co-operation of consumers with regard to payment and managing their water consumption effectively is an important business aspect (see Pollit, 1995).

The quest for a suitable centre

Such ideas need to be tested however well they are thought out. A suitable centre is sought to apply the models. Botswana was suggested.

- Being a water scarce country it realizes the value of water and is already ahead in water management strategies.
- Technologically it has the ability to develop systems, do research and manage implementation of water projects.
- It is institutionally capacitated and transparent.
- The Departments of Water Affairs and local government are empowered to implement water projects.
- Financially the country is sound and it forms a good base for international funders and private partners.
- It has developed water policies and regulations.
- It has experience in rural and urban water supply and sanitation implementation.
- It is respected politically in Africa.

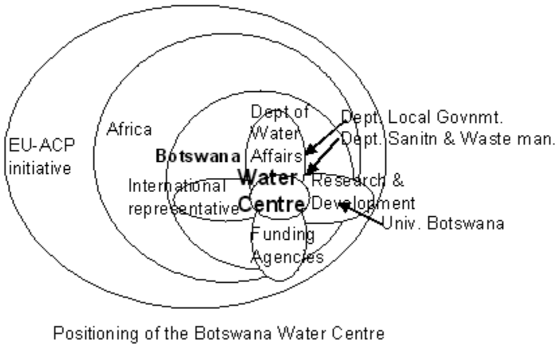


Figure 2 How a Water Centre will assist in financing

The quest for a suitable model

There is a need for public, private and community involvement if the most acceptable model is to be found to provide water services. The public authority has the background knowledge and provides continuity, the private sector has managerial skills, but the community are the ones who have to pay in the end and must be given the correct balance between service quality and price.

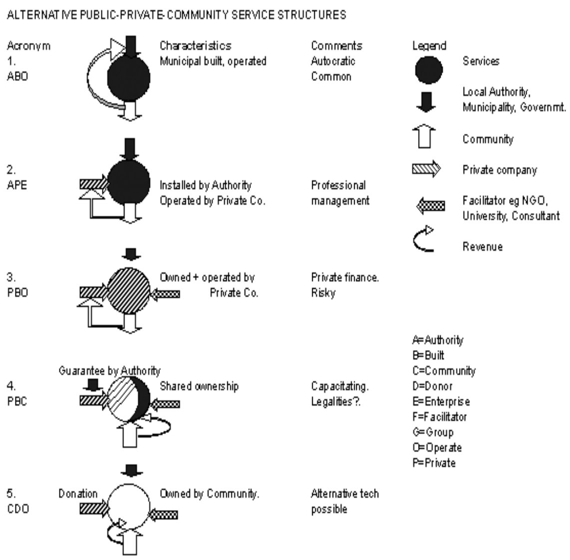
Figure 3, various combinations of partnership of the three parties are depicted. The black arrows denote public, the hatched arrows private and white arrows community.

The six models are;

- ABO Authority built and operated
- APE Authority-private enterprise built and operated
- PBO Privately built and operated
- PBC Privately built, community owned
- CDO Community by donation owned and operated
- CBO Community built and operated

Successive schemes are drawn with increasing community input. The first is often objected to by the community, whereas the last is likely to have management problems. Model 4 will let all parties become involved, but Model 5 may be preferred by some donors if there is an apparent lack of institutional capacity. In all cases the interest and responsibility of the community is expected to be increased. ●

Figure 3 Alternative privatization models



References

Briscoe, J. (1997) Managing water as an economic good: rules for reformers. Water Supply, 15(4), 153-172, Blackwell Science Ltd.

Dinar, A., Rosegrant, M.W. and Meinzen, Dick R. (1997) Water Allocation Mechanisms. World Bank Policy Research Working Paper 1779.

Jackson, B.M. and Hlahla, M. (1999) South Africa's infrastructure service delivery needs: the role and challenge for public private partnerships. Development Southern Africa, 16(4).

Lyonnaise des Eaux (1998) Range of Options for Private Sector Involvement in Municipal Water and Wastewater Service. Paris.

McLeod, N. (1997) Tariffs and payment for services- The Durban story. Civil Engg, SAICE, June..

OFWAT (Office of Water Services) (1997) Birmingham, U.K.

Perrot, J-Y and Chatelus. G. (Eds) (2000) Financing of Major Infrastructure and Public Service Projects: Public-Private Partnership. Presses de l'école nationale des ponts et chaussées.

Pollit, C. (1995) Managing Techniques for the Public Sector, In Pulpit and Practice, Eds. G Pales and D. Savoie, Kingston McGill Queen Univ. Press.

Richardson, A.E. (2002) Decision support system for optimizing strategies for the financing and implementation of municipal water services. MSc(Eng) thesis, University of the Witwatersrand.

Roth, G. (1987) The Private Provision of Public Services in Developing Countries. EDI series in Economic Development, published for the World Bank Oxford Univ. Press.

Paper presented at LESAM 2007 – 2nd Leading Edge Conference on Strategic Asset Management

A GIS based approach to assess the vulnerability of water distribution systems

It is a fact that water distribution systems in most European cities are reaching the end of their lifetime; pipe breaks and leaks have significant increased in the last few years, and there is no evident reason for the future trend to be inverted in the short-term horizon. The history of water networks rehabilitation leans on the so called reactive approach: first the failure occurs, then comes the intervention. Efforts are recently being undertaken in order to establish a rational framework for maintenance decision-making in water distribution systems, based on a new logic: a rehabilitation carried out before the problem takes place is to be preferred, thanks to its higher effectiveness and to the troubles it is able to prevent rather than cure (pro-active approach). Nevertheless, the experience demonstrated that availability of data is sometimes the first problem to be addressed and the application of advanced management approaches is sometimes unfeasible because of the lack of a long term monitoring strategy. Information about the asset and the surrounding environment are often available at the municipality archive, but not recorded in a way to be directly applied for maintenance actions planning.

The aim of this study was to develop a simple but feasible model to assess the vulnerability of an Italian water distribution systems suitable with the level of data available: starting from a typical Italian case study, we defined what can be evaluated, analysed or calculated according to what can be obtained from the Utility in terms of data quality and quantity. The selected case study is the drinking water system of Reggio Emilia, located in the northern part of Italy, managed by ENIA SpA.

Tonio Liserra, Rita Ugarelli, Vittorio Di Federico and Marco Maglionico in this paper, after an introduction on asset managements practice, state the definition of reliability variable and criticality index applied in order to run a simplify vulnerability model and presents the results achieved in Reggio Emilia up to this stage of development.

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Introduction

Under the present national legislation (Law n°36, 1994), Italian water distribution systems are required to achieve higher management efficiency. In urban distribution systems, challenging goals in level of service have to be achieved by utilities in reducing costs and improving the serviceability.

European projects developed during the 5th Framework Programme, focused on water asset management, have been looking at risk in terms of economic, social and environmental probability of failure considering that system knowledge is a pre-requisite for obtaining an efficient system management.

However, the experience demonstrated that availability of data is sometimes the first problem to be addressed and the application of advanced management approaches is sometimes unfeasible because of the lack of a long term monitoring strategy. Data on failure paths in urban networks is piecemeal and not available for feeding complex risk-based approaches and a complete damage analysis is not practical (multi-objective approaches; failure modes and effects analysis; etc.). In reality, risk and its perception permeate the decision making process and, providing better insights of the system, the use of advanced technologies will be able to better support informed decision making about system management and rehabilitation, empowering the existing tools and approaches.

Information about the asset and the surrounding environment are often available at the municipality archive, but not recorded in order to be directly applied for maintenance actions planning. Frequently data can be found in departments belonging to the same municipality but grouping data is a demanding task because the collaboration between different areas of management is not efficient or virtually non-existent. Even when a centralised database is available, it may be impossible to use it due to improper linking between information fields of the database, or because data quality is insufficient; as a consequence, a complete asset analysis cannot be performed. In addition, asset data should be geo-referred in a centred GIS-based system. The aim of this study was to build a complete database for the tested municipality in a GIS interface and define asset criticality indices correlating asset performance, conditions, and location with the computed hydraulic criticality indices in different scenarios of system components failures. The following step will be to judge if new synthetic indices should be defined to describe the quality of service according to levels of service established by municipality or if indices already available in literature can be directly assumed and applied to drive decision making in planning rehabilitation strategies.

Vulnerability analysis of a drinking water system: methodology

In order to perform a feasible and suitable vulnerability analysis for the Reggio Emilia network, the research started with the evaluation of the real availability of data that will be described in the following 'case study' in detail. According to the dataset provided by the utility dealing with failure data and hydraulic model results, with additional information on other service like wastewater pipes asset and gas pipelining and land use, a simple and practical methodology have been developed based on the following steps:

- asset inventory and data analysis;
- computation of structural reliability of the system components;
- computation of the hydraulic reliability of the system components;
- definition of sensitive areas and sensitive customers;
- definition of a suitable index to compute pipe criticality including structural, hydraulic performance in combination to the level of sensitivity of customers;
- creation of easy-to-read thematic maps.

Table 2 Pipes material as percentage of pipes length, population, supplying pressure in the three DMA's of Reggio Emilia

DMA	Unit	D1	D2	D3
Steel (ST)	% of total length	3.69		
Fibre Cement (FIB)	"	18	19	21
Cast iron (CI)	"	8	8	10
Polyethylene (PE)	"	49	53	58
polyvinyl chloride (PVC)	"	22	20	12
Total length of pipes	m	9269	5121	8644
Estimated population	inhabitants	4700	2700	5100
Supply pressure	m H_2O	40	40	38

The asset and data description is analysed in the chapter of this paper named 'case study', while the thematic maps are described at the chapter 'result and discussion'.

Structural reliability of pipes

The structural reliability R(t) of a component is defined as the probability that the component experiences no failures during the time interval (0,t) from time zero to time t, given that it is a new one or repaired at time zero. In other word the reliability is the probability that the time to failure T exceeds t, or:

$$R(t) = \int_t^{\infty} f(t)dt$$

(1)

where *f(t)* is the probability density function of the time to failure. Values for *R(t)* range between 0 and 1. The probability density function *f(t)* may be developed from equipment failure data. Because the time to failure of a component is not certain, the expected life of the component under investigation has to be estimated. Furthermore, for a repairable component, the time required to repair the failed component might also be uncertain.

You can define the Mean Time To Failure (MTTF) as the expected value of the time to failure, stated mathematically as:

$$MTTF = \int_0^{\infty} tf(t)dt = \int_0^{\infty} t\lambda e^{-\lambda t}dt$$

(2)

which is expressed in years. From equation (2), the MTTF of a component having an exponential failure distribution is simply the inverse of the parameter λ. The parameter λ per each pipe's class (defined by material and diameter) is estimated directly from the break dataset as:

$$\lambda_c = \frac{N}{Y \times L}$$

(3)

Where N is the total number of burst per class of pipes, L is the total length of pipes in each class and Y is the observation period. Given the mean break rate (br/yr/km) for a pipe it is possible to calculate its parameter λ (br/yr) multiplying the mean break rate by its length and then it's possible to evaluate the MTTF as λ^{-1}.

The hydraulic reliability of network components

The hydraulic reliability of a drinking water pipe can be defined as the ability of providing the flow request at each node under the pressure and demand conditions of the network.

Table 1 Impact Coefficient applied in Reggio Emilia to evaluate the social impact of a reduced supply to customers

Customer type	Impact coefficient
Hospital	10
School	5
Commercial, farm and industry	1
Residential area	1

In order to compute the hydraulic reliability of the Reggio Emilia network two models have been s elected, RELNET (Eisenbeis et al., 2002a) and FAILNET-RELIAB, (Eisenbeis et al., 2002b) respectively developed by BUT (*Brno University of Technology,* Czech Republic), and CEMAGREF (*Institut de recherche pour l'ingénierie de l'agriculture et de l'environnement*, France) during the CARE-W project (Sægrov S., 2004), EU project funded by EU Commission under the fifth Framework Programme (EVK1-CT-2000-00053).

Data needed for the simulation include:

1) Network information:
- topology;
- length, diameter and roughness coefficient for each pipe;
- pump curve for each pump.

2) demands and boundary conditions:
- demands at nodes;
- given heads at tanks.

3) failure and repair probabilities, only for FAILNET-RELIAB:
- form and parameters for inter-failure time probability distribution function for each component that is subject to failure;
- form and parameters of repair duration probability distribution function for each such component.

RelNet

The aim of this model is to assess hydraulic reliability of each node, the total hydraulic reliability of the network and hydraulic critical index (HCI) of each pipe section. Reliability of the water distribution network depends on reliability of network elements, nodes and pipe sections. Reliability is based on required pressure in each node and undelivered water in whole network. Hydraulic reliability of components is evaluated by discarding one pipe per time and running the hydraulic simulation without it. Hydraulic computation is

Table 3 Diameter classes defined in Reggio Emilia network

Class Diameters	
1 (125 ÷ 250)	4182 m
2 (75 ÷ 110)	14952 m
3 (25 ÷ 65)	3904 m

performed by running EPANET model (Rossman, L., 2002).

The tool computes the so-called Hydraulic Criticality Index (HCI) at pipe level. The HCI describes the impact of the j-th pipe failing on the total network reliability. The parameter ranges in the interval <0,1> where 1 stands for a very important system component.

$$HCI = \frac{Q_{tot} - Q_{new}}{Q_{tot}}$$

(4)

Where:
Q_{tot} id the total flow of the network with all the components operating;
Q_{new} is the flow in pipes after elimination of one component.
A higher value of *HCI* means a higher impact of the discarded link on the total network reliability. If the sum of $Q_{new} = 0$ then no demand is satisfied in all nodes of the network and $HCI = 1$.

If sum of $Q_{new} = Q_{tot}$, than $HCI = 0$ that means the demand is fully satisfied at the required pressure.

Failnet-Reliab

In this tool reliability is defined in the sense of water demand satisfaction, and, basically, it is the quotient between the available consumption and the water demand.

After a specific hydraulic modelling, where available consumption is computed according to the head at each node, several reliability indices are assessed. The different scales of assessment are:

- pipes: this is the impact of a pipe break on all the nodes of the network;
- nodes: this is the reliability of supply at the node in relation with all the nodes;
- global network (or a sector): this is overall reliability of the network.

The model runs at two steps:

- First an hydraulic model is computed. Newton-Raphson method is used to solve hydraulic equation and compute the outputs.
- Secondly reliability indices are assessed. They depend on the results of hydraulic models (with or with out pipe breaks), on weight of each nodes (quantity, vulnerability) and on pipe failure probabilities. They represent the volume of non-supplied water in the year because of failure risk.

Two values are computed for each pipe:

Table 4
Failure events recorded for the period 1994-2006 per each diameter and material

Material:		PE	FIB	PVC	CI	ST
Diameter	250	1	0	0	0	0
	200	6	2	0	1	0
	160	11	0	1	0	0
	150	0	3	0	0	0
	125	0	1	0	0	3
	110	24	0	12	0	0
	100	0	12	0	1	0
	90	9	0	8	0	0
	80	0	22	0	8	0
	75	0	0	0	0	0
	65	0	0	0	1	0
	63	16	0	0	0	0
	60	0	1	0	0	0
	50	1	0	0	17	0
	40	0	0	0	0	0
	32	1	0	0	0	0
	25	0	0	0	0	0

Table 5
Mean break rate (br/yr/km) for other Agencies in Emilia-Romagna Region (Bizzarri et al.,2000)

Municipality	Reggio Emilia	Ferrara	Ravenna	Imola	Bologna
Mean Break Rate	0.155	0.294	0.202	0.159	0.168

- the hydraulic criticality index (HCI, between 0 and 1, where 1 stands for a very important system component),
- the volume non-supplied caused by failure risk (HCI_V in m³).

Definition of sensitive areas and sensitive customers

The impact of the failure of delivering a reduced flow compared to the customer demands is influenced by the different sensitivity of customers on water use and consequent possible business or social risk. Network nodes, pipes and plants can be classify with impact coefficients able to take into account the possible effect produced by its 'out of order' probable state. The impact coefficients can be defined according to the number of connections to include the size of the area served by the single components and by the type of customers served (shops, hospital, private, farms, schools, for instance). Users identification, characterization and prioritising is mandatory at this stage of the research.

Table 1 describes the impact coefficient selected with the aim of example and applied to the Reggio Emilia case study. The definition of impact coefficient has been based only of customer typology for the moment.

Vulnerability coefficient

In order to develop thematic maps, a general coefficient to compute the network components vulnerability according to the data availability of Reggio Emilia has been defined.
To each pipe can be addressed the following coefficient, named 'Vulnerability':

$$V_c = P_F \times HI \times f(w_i)$$

(5)

Where:
P_F is a weight defined by the utility's managers to prioritize level of service to be achieved, or, similarly, the failures to be reduced in order to achieved defined level of services;
HI (Hydraulic Impact) Hydraulic reliability index;
$f(w_i)$ it is the impact coefficient previously defined.

Case study: Reggio Emilia's drinking water system

The drinking water supply network of

Table 6
Reliability parameter per different pipe's material and diameters

Material	**D (mm)**	**L tot (m)**	**Break**	**λ c**
PE	D ≥ 200	1187	7	0.45352
PE	90 ≤ D ≤ 160	8191	44	0.41321
PE	D ≤ 63	2805	18	0.49364
FIB	D ≥ 150	855	5	0.44971
FIB	100 ≤ D ≤ 125	1442	13	0.69328
FIB	D ≤ 80	2094	23	0.84497
PVC	D ≥ 160	224	1	0.34407
PVC	D ≤ 110	3860	20	0.39857
CI	D ≥ 125	144	1	0.53256
CI	80 ≤ D ≤ 100	1015	10	0.75760
CI	D ≤ 65	871	18	1.58897
ST	80 ≤ D ≤ 125	341	3	0.67730
GCI	70 ≤ D ≤ 110	8	0	0.00000

Table 7 Example of computed MMTF for the Reggio Emilia network and applied as input to FAILNET-RELIAB

Pipe ID	Length (m)	Diam. and Material	λ	MTTF (years)
5038	48.72	110 PE	0.02013	49.7
5039	47.29	80 GH	0.03583	27.9
5040	22.10	80 GH	0.01674	59.7
5041	34.59	80 GH	0.02621	38.2
5042	112.48	63 PE	0.05553	18.0
5064	2.99	80 GH	0.00227	441.5
5065	92.20	80 FIB	0.07791	12.8

the historical centre of Reggio Emilia has been chosen as case study: it supplies 140,000 inhabitants with a 2200 m^3/h water demand and has 700 km length. The hydraulic model is divided in three district meter areas (DMA) named D1, D2 and D3.

Each DMA is a discrete part of the water distribution system separated from neighbouring DMA's by means of closed sluice valves, commonly termed as boundary valves. DMA's are connected to the transmission mains in only one entry point.

Available data

The failure database for the three DMA's has been provided by ENIA S.p.A.. The database includes the failure events registered from 1994 to 2006.

According to a preliminary analysis, several events were found to be due to external causes and therefore were not considered in our investigation. To select relevant data for further analysis, breaks were classified as i) due to external causes; ii) imputing breaks to intrinsic reliability of the pipes. In case i), breaks are mainly due to excavations close to the pipe, due to contacts with other utilities (electric, telephone, gas); they are frequent, but not related to pipes reliability, and were therefore excluded. Data belonging to the resulting subset were analysed, and classified either as house connection breaks and main network breaks; a preliminary investigation showed that the break rate was higher in house connection than in the rest of the network. A possible explanation for the high incidence of breaks in house connections includes: small diameter (small pipes seem more amenable to breaks, as noted by D. Kelly O'Days, 1982) and low depth, which increases the likelihood of interfering with other underground services. We omitted any further analysis of house connections breaks, and focused on breaks in the distribution network.

At the end of the registration phase, data were analysed to determine the characteristics of the distribution network (total length, length per material and/or diameter, etc.) and the distribution of breaks in space and time for the system.

Other data provided by ENIA are:

- water distribution network shape files for the three DMA's;
- wastewater, gas and electricity networks maps;
- streets maps;
- the EPANET 2, hydraulic model for the three DMAs;

To allow the evaluation of the traffic load, the Agency for the public transports provided the research with the routes and time schedules of bus crossing the historical centre of Reggio Emilia.

To compute the social effect and indirect costs of failures drawings, maps and records on building assets and codes, in addition to information on land use and population growth in 1997 and 1998 have been collected from different sources.

Data analysis

The population served by each DMA's is of 4700 inhabitants for district D1, 2700 inhabitants for district D2 and 5100 inhabitants for district D3.

The material distribution compared with the pipes lengths is quite homogeneous in the three DMA's with the two exceptions regarding steel laid only in district D1 and grey cast iron available, in small percentage, in district D3. Table 2 shows an inventory of the population served, the supply pressure at reservoirs and the distribution network piping compare with pipes length.

In order to try and determine how the pipe break rate is influenced by pipe diameter, three diameter-based classes were identified (Table 3): Class 1 includes pipes with diameters between 125 mm and 250 mm, class 2 includes pipes with diameters between 75 mm and 110 mm and class three pipes with diameter between 25 mm and 65 mm.

Analysis of break events

The study focuses on breaks in pipes during the period 1994-2006. Available data were analysed according to the criteria outlined in the paragraph describing the available data; the resulting data subset consisted of 162 break events. The record corresponding to each break event included the date, the address, and in some cases, additional information as well, such as the necessary type of repair.

Results of the analysis included:

- location of breaks on city maps;
- computation of the number of breaks for each material;
- computation of the break rate for each material;
- examination of the correlation between break rate and pipes diameter.

The mean break rate for the period 1994-2006, computed by dividing the total number of pipe breaks by the length of the distribution network, is computed in (br/yr/km); the same format is used here after.

The mean break rate for the entire network is comparable to that obtained for other Agencies in Emilia-Romagna Region (Bizzarri et al., 2000), as shown in Table 5.

In order to run the reliability model FAILNET-RELIAB, breaks data has been analysed with the aim of computation of the Mean Time To Failure (MTTF).

Table 6 shows the computed reliability parameter λ per different pipe's material and diameter that has been used for the computation of the pipe's MTTF, as:

$$MTTF = \frac{1}{\lambda}$$

(6)

Results

The Reggio Emilia drinking water network vulnerability has been evaluated at three different levels according to the data availability.

First level approach

The first level of study has been performed analysing only the hydraulic reliability of the components of the network. The hydraulic reliability has been computed as the he volume non-supplied caused by pipe's breaks. The analysis does not include neither the probability of break of pipes nor the sensitivity of customers.

The first level of analysis has been run applying the RELNET model and simulating the break state of pipes and evaluating the hydraulic consequence on the whole network eliminating one pipe per time from the EPANET input file.

The vulnerability is simply given by the equation:

$$HI=HCI$$

(7)

Results have been produced in table format (example in Table 8) and as thematic maps (Figure 1).

The pipes are visualized in the maps with colours in order to give a quick

Table 8 Example of vulnerability classification of pipes on the basis of first proposed level analysis

Vulnerability	Pipes
High	[282, 140, 235, 1, 234…]
Medium	[78, 79, 72, 71]
Low	[13, 12, 14, 27, 26…]

Figure 1 Vulnerability map on the basis of the RELNET model

and easy understanding on the level of vulnerability. The increasing climax of vulnerability is given by colours in the following sequence: red, brown, blue, dark green and light green.

As shown in the map, Figure 1, the reliability analysis of hydraulic performance of the network assesses, as most critical or vulnerable

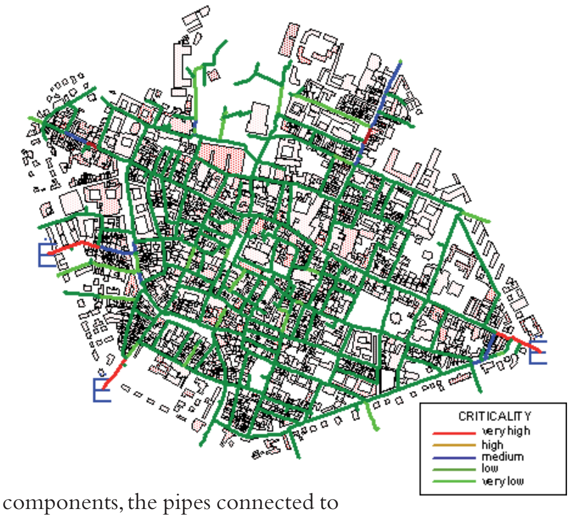

Figure 2 Vulnerability map on the basis of the FAILNET-RELIAB model

components, the pipes connected to the supplying reservoirs and the pipes connecting different areas of the network with a branch topology. If any one section of water distribution main fails or needs repair, that section connected can be isolated with disrupting all users on the network.

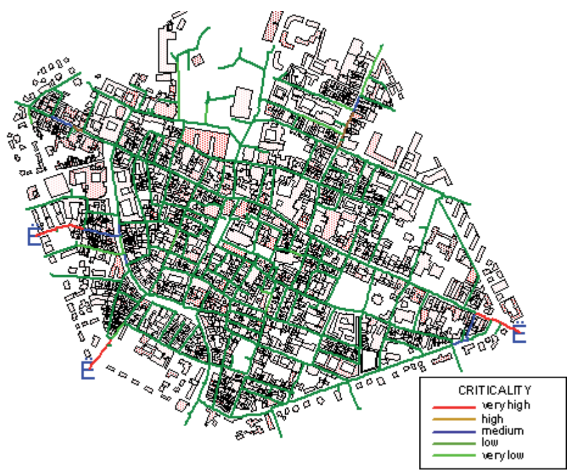

Figure 3 Vulnerability map on the basis of the FAILNET-RELIAB model, third level

Second level approach

The second level of study has been performed analysing the hydraulic reliability of the components of the network including the probability of break of the single pipes according to the computed MTTF. The analysis does not include the sensitivity of customers.

The second level of analysis has been run applying the FAILNET-RELIAB model.

Results have been produced as thematic maps (Figure 2).

Third level approach

The third level of study has been performed analysing the hydraulic reliability of the components of the network including the probability of break of the single pipes according to the computed MTTF including the sensitivity of customers as stated in Table 7.

The third level of analysis has been run applying the FAILNET-RELIAB model.

Results have been produced as thematic maps (Figure 3)

With the comparison of the three level of analysis (Figures 1, 2 and 3) a fairly similar selection of critical components can be noticed.

Slight differences are visualized, for brown, blue, dark green and light green colors, when increasing the level of analysis from simply hydraulic reliability to hydraulic reliability connected to structural reliability and including customers sensitivity. Comparing Figure 2 and 3, for instance, some pipes show a lower vulnerability when including customer sensitivity. As a matter of fact, including the impact that a probable failure can produce to customers with different sensitivity to water needs, changes the vulnerability levels of pipes with the same probability of failing: indirect costs, linked to social impact or social costs, in fact increases the more sensitive the customer supplied is.

Considerations like the latter, apparently effortless, are instead basic rules to be applied in rehabilitation planning in order to priorities components to be included in maintenance programmes.

The example described takes into account only one failure and only one impact coefficient to address vulnerability. However, a more comprehensive analysis should be addressed by utilities managers to rank pipes criticality looking at the capacity of providing the customer with an efficient system and optimal level of service.

Conclusion

The aim of this study was to develop a simple but feasible model to assess the vulnerability of an Italian water distribution systems suitable with the level of data available: starting from a typical Italian case study, we defined what can be evaluated, analysed or calculated according to what can be obtained from the utility in terms of data quality and quantity. The selected case study is the drinking water system of Reggio Emilia town located in the northern part of Italy, managed by ENIA S.p.A.

According to the dataset provided by the utility dealing with failure data and hydraulic model results, with additional information on other service, a simple and practical methodology have been developed.

The model, integrating hydraulic and structural reliability, customer sensitivity to water use and GIS features, provides the utility's managers with the list of most vulnerable pipes in table and thematic maps format.

Results of the case study are described in this paper to point out the influence of including impact coefficients in a methodology finalised to rank pipes for rehabilitation aim: pipes with similar operational condition and same probability of failing can have different impact magnitude if not perfectly performing according, for instance, to the typology of customer served.

In terms of asset management, the results show that rehabilitation projects, with same or similar direct costs, can eventually have different total costs when including indirect costs analysis. ●

References

Bizzarri, A., Di Federico, I., Di Federico, V. & Mazzacane, S. (2000). Reti di distribuzione idrica urbana: indagine di affidabilità. Franco Angeli Editore.

Eisenbeis, P., Le Gat, Y., Laffréchine, K., Le Gauffre, P., Konig, A., Rostum, J., Tuhovcah, L. & Valkovic, P. (2002a). Care-W (EVK1-CT-2000-00053) Report 2.1.

Eisenbeis, P., Poulton, M., Laffréchine, K. & Le Gauffre, P. (2002b). Care-W (EVK1-CT-2000-00053) Report 2.3.

Kelly D. O'Day (1982). Organizing and Analyzing Leak and Break Data for Making Main Replacement Decisions. Jour. AWWA, Nov. 1982.

Rossman, L. (2002) Epanet 2. Users manual

Sægrov S., (2004) CARE-W Computer Aided Rehabilitation for Water Networks, IWA Publishing, Alliance House, 12 Caxton Street, London SW1H 0QS, UK.

Paper presented at LESAM 2007 – 2nd Leading Edge Conference on Strategic Asset Management

Strategic Asset Management: Invited papers from the IWA Leading Edge Conference on Strategic Asset Management (LESAM), Lisbon, October 2007

Editor: H Alegre

Water and Wastewater companies operating all around the world have faced rising asset management and replacement costs, often to levels that are financially unsustainable.

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Performance Assessment of Urban Infrastructure Services: Drinking water, wastewater and solid waste

Editors: Enrique A Cabrera, Jr. and Miguel Angel Pardo

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Author: Simon Pollard

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For operators, risk management is now regarded as a key business function. Understanding risk and being able to implement risk management is critical to the provision of safe drinking water. As part of a move towards a more strategic, forward looking approach to utility management, the IWA is promoting a risk-based approach to water utility management, from catchment to tap, through the implementation of the Bonn Charter (2004).

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Asset Management Research Needs Roadmap

AwwaRF Report 91216

Authors: A Graham, G Kirmeyer, E Wessels, E Tenny, D Harp, S McKinney, C Saill, B Templin, D Hughes, and J Fortin

Many utilities are uncertain about asset management, have delayed or scaled down implementation efforts, and do not see a clear path for embarking on a comprehensive asset management program. There is currently no strategic industry focus for the planning and funding of future research efforts in the area of asset management for water and wastewater utilities. As such, AwwaRF recognized a need to gather the key utility subscribers and stakeholders together to help develop an asset management research needs roadmap with an emphasis on drinking water systems.

The goals of this project were to assemble key organizations and experts to evaluate the available asset management information and identify future water and wastewater community needs that research could help solve. The report will summarize the asset management landscape, identify critical information gaps, develop research project ideas, and generate a strategic approach for the funding of research to fill the gaps.

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AM DIARY

A listing of upcoming asset management-related events and conferences. Send event details to WAMI for inclusion.

PR09 Conference: Water Company Investment Plans – Stakeholder views
26th November 2008, London, UK
Contact Bob Earll, CMS
Tel: 01531 890415
Email: bob.earll@coastms.co.uk

International Conference Water Efficiency in Urban Areas: Concepts, Technologies, Socio Economics
29-30 January 2009, Wuerzburg, Germany
Contact: Gabriele Struthoff-Mueller
Email: gabriele.struthoff-mueller@otti.de
Web: www.otti.de/pdf/wea3091.pdf

3rd Specialised Conference on Decentralised Water & Wastewater International Network
9-11 February 2009, Kathmandu, Nepal

Water Loss 2009
26-29 April 2009, Cape Town, South Africa
Email: waterloss2009@randwater.co.za
Web: www.waterloss2009.com

2nd International Conference on Water Economics, Statistics & Finance
3-5 July 2009, Alexandroupolis, Greece
Contact: Konstantinos Tsagarakis
Tel: +30 28310 77433 or +306945706431
Email: iwa@econ.soc.uoc.gr
Web: www.soc.uoc.gr/iwa

Asset Management of Medium and Small Wastewater Utilities
3-4 July 2009, Alexandroupolis, Greece
Contact: Konstantinos Tsagarakis
Tel: +30 28310 77433 or +306945706431
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