the international water association

Digital Water

The role of Instrumentation in Digital Transformation

the international water association

Digital Water

The role of Instrumentation in Digital Transformation

Author
Oliver Grievson
Technical Lead at Z-Tech Control Systems

Foreword

One of the greatest advantages of digitalisation is the possibility to obtain real-time data. This can be used to monitor the performance of a system, detect errors as they are happening, and regulate and optimise variables of a process. More advanced digital tools can also simulate a real system (i.e. Virtual Reality) and allow trial experiments in a safe environment (i.e. Digital Twins).

Digitalisation of the water sector is gathering and creating a conspicuous amount of data that can be effectively harnessed to improve operations, while adding value to the sector. To make use of this data, firstly the information received from digital tools must be interpreted correctly, and secondly the tool itself has to be functional and operated correctly. Interpreting data correctly requires capacity building and training of operators. Functional instruments require efficient installation, monitoring and operation. The right instrumentation allows for situational awareness of the system and facilitates informed decision-making. This paper focuses on how to select the appropriate instrumentation, as well as how to operate and maintain it.

The International Water Association (IWA) is inspiring the water sector to adopt a smarter approach to water management. Through the IWA Digital Water Programme, the association provides a platform where water professionals can exchange knowledge, challenges faced, and effective solutions towards the Digital Transformation of our sector. The programme is producing a Digital Water white paper series to provide insights into core aspects of the digital world. This latest paper discusses the importance of appropriate instrumentation - which is the main source of digital data and is the starting point of Digital Transformation.

At IWA, we believe it is essential to generate and share knowledge and best practice. In this digital era, only by sharing common challenges and effective solutions, can we ensure the ongoing improvement of our sector. Doing so will improve productivity, reduce our carbon footprint, and ultimately lead to improved outcomes in water management and sanitation.

Kalanithy Vairavamoorthy
Executive Director of the International Water Association

Summary

This white paper focuses on the importance of instrumentation as the source of information for the Digital Transformation. The aim is to highlight the crucial role that the right instrumentation has in improving situational awareness and in facilitating informed decision making. The examples shown here were selected to demonstrate simple and more complex uses of instrumentation and how this can be used to realise immediate benefits for the water sector.

Introduction

The concept of the Digital Transformation, especially in the Water Industry, includes a broad category of techniques and methods that can be used to allow the industry to operate with more efficiency and to make decisions based upon an informed way of working. From the use of modelling techniques to the use of concepts such as Digital Twins, there are common factors that underpin every aspect of Digital Transformation, i.e. the use of data and the source from where that data has come from (usually, but not exclusively, some form of instrument that is recording this data).

In terms of Digital Transformation, Instrumentation can be defined as: *"A set of techniques to measure, transmit, record and regulate physical or chemical variables. Instrumentation is needed to acquire information of a process variable, to be able to react manually or automatically (control actions) to maintain the process in a desired operational point."* This includes instrumentation for acquiring information but also valves and controllers for process control.

With reference to instrumentation and its role in the digitalisation of the water sector, key areas of this whitepaper include:

- the importance of instrumentation and its role in Digital Transformation;
- the resistance to the effective use of instrumentation;
- the instrumentation life cycle and how the different elements of the life cycle can be used to realise the benefits of both instrumentation and Digital Transformation;
- some examples of actual case studies where simple and more complex uses of instrumentation can be used to realise immediate benefits.

This paper is a part of a series of white paper under the IWA Digital Water Programme (IWA, 2019) which aims to generate and share knowledge on digitalisation of the water industry. The IWA Digital Water Programme acts as a catalyst for innovation, knowledge and best practice; and provides a platform to share experiences and promote leadership in transitioning to digital water solutions. By sharing experience on the drivers and pathways to digital transformation in the water industry, the programme is consolidating lessons and guidance for water utilities to start or continue to build their journey towards digitalisation.

The role of instrumentation in Digital Transformation

Instrumentation is a fundamental part of the Digital Transformation of the water industry as it is the fundamental source of digital data. Instrumentation is present throughout water and wastewater systems and ranges from the use of Smart Meters at a customer's premises to industrial instrumentation on the various network and treatment work systems within the water industry.

All the examples of where Digital Transformation has succeeded in the water industry so far have been based upon three basic tenants (1) good quality data from properly installed instrumentation; (2) a basic knowledge of the uncertainty of the data; and (3) a robust instrumentation maintenance processes, making sure that instrumentation accuracy is maintained. Conversely, it has been poor quality data, from either poorly installed or poorly maintained instruments, that has resulted in the failure of some of the most promising Digital Transformation projects.

For the success of the projects, a data and information strategy is needed. This strategy can be in a specific area, such as non-revenue water, or in a more generalised company-based operational area. An example of this is in the Global Omnium Digital Twin model built for the City of Valencia (Conjeos, 2020). This application-specific Digital Transformation project saw instrumentation installed along with dual redundancy on telemetry outstations, coupled with an understanding of the accuracy of the instrumentation using general uncertainty principles. This has allowed the construction of a hydraulic digital twin that enables operators to not only understand the system performance but also to predict future outcomes. Such functionality can only be achieved using accurate instrumentation which is ideally coupled with the instrumentation meta-data to provide full functionality of both visualisation and analytics.

Clearly, with the right instrumentation, situational awareness of the system can be achieved thus facilitating informed decision making, which is where the value exists for companies within the water industry. As an industry, we know that accurate instrumentation is an absolute must but does not always exist. Why not? Is this due to resistance to the effective use of instrumentation?

Resistance to the effective use of instrumentation

Resistance to the effective use of instrumentation usually starts when instruments are not installed correctly or have been installed for little or no purpose. In these circumstances, there can be a perception that an instrument is not correct which, in turn, leads to lack of maintenance of the instrument and, therefore, additional wrong measurements. This leads to a vicious circle where the instrument provides inaccurate or useless data (i.e. useless information) and it is consequently abandoned. The risk in this approach lies in the use of incorrect data which, in some cases, can cause poor control of the treatment works and result in regulatory issues. The root cause of a lack of trust in instrumentation is due to:

Instrument reliability

There is resistance to the use of instrumentation to full effectiveness as it is perceived as unreliable. This can be true if an instrument was badly installed or installed in the wrong place. However, in other cases, the instrument reliability is compromised by poor maintenance;

The threat of instruments

The perceived threat that instrumentation and automation will be used to retrench or replace the workforce. On the contrary, instrumentation should be a tool for operators to operate more efficiently by reducing the time spent manually analysing samples;

Over-design of the automation system

The design and then use of instrumentation so that the system is over-complicated and un-operable. This causes a gap between the design engineer and the user;

Poor use of current data and poor data management

Instrumentation that is currently in place at treatment works normally feeds through to a SCADA (supervisory control and data acquisition) system. However, the vast majority of data that the instruments produce is generally not used, leading to “data richness but information poverty”;

A lack of understanding of what instrumentation can achieve

There is generally a poor knowledge over what instrumentation can achieve to deliver process control/advanced process control. Poor integration of the current instrumentation leads to the loss of most of data and information that instrumentation produces, which results in poor efficiencies in current process control and the inability to utilise the instrumentation to its full effectiveness;

Lack of trust in instrumentation

Instrumentation is not trusted from the operator level, to the corporate level or at the regulatory level therefore, it cannot be used for regulatory compliance.

Below are some examples where some of these factors have influenced problems in the use of instrumentation. Figure 1 shows a typical wastewater flow measurement system being monitored for regulatory purposes using an electro-magnetic flow meter.

Figure 1 Poorly installed flow to full treatment flow meter.

An accurate flow meter could be used:

(A) as a pollution warning monitor in ensuring expected flows are received by the works;

(B) to control the secondary treatment process to increase the efficiency of the treatment works;

(C) to portray a true situation awareness of the operation of the works treatment systems and its performance; and

(D) in terms of the long-term information for asset planning purposes as to whether the data indicates growth or infiltration in the wastewater network.

However, due to poor installation of the flow meter, none of the above can be achieved in this case. This flow meter is directly in front of an actuated control valve and so the accuracy of the data is being compromised. The flow meter is being used to control the pass forward flow which, because of the error of measurement, is causing a semi-permanent discharge to the site storm tanks and potentially affecting the environment due to poor flow measurement and poor flow control, hiding the true performance of the treatment works. This is the direct consequence of the data's poor accuracy.

It is not only poor installation that can influence the resistance to the effective use of instrumentation. Figure 2 shows a large flume which was measuring inaccurately. The lack of maintenance, due to poor access to the flumes caused by the use of heavy covers, prevented effective maintenance resulting in poor performance of the flow measurement system. This had a similar effect to the example in Figure 1. In this case, however, the lack of maintenance, and therefore the inaccurate measurement, gave the impression that the treatment work was non-compliant to the regulatory limits. This was caused by a build-up of grit that cause a false high reading of the level-based flow technique. This triggered the false appearance of the need for capital investment "due to growth". Once properly maintained, the resulting

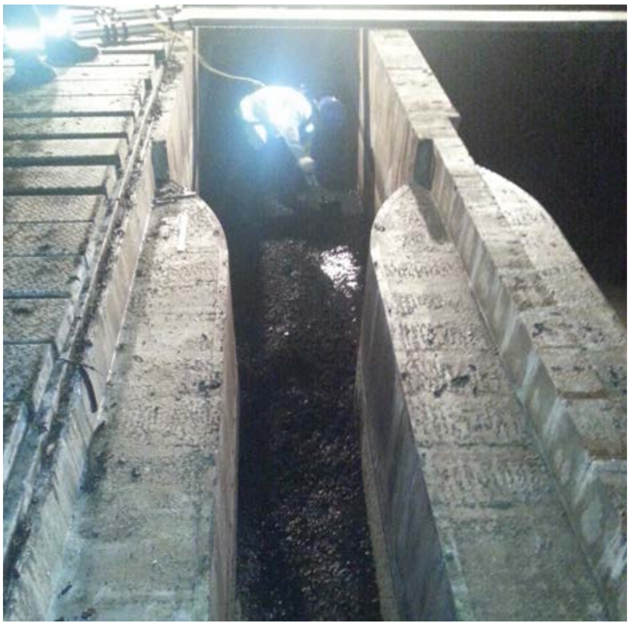

Figure 2: A large flume influenced by poor maintenance procedures allowing grit build up.

Figure 3 – Poor installation can breed poor maintenance. This control valve, installed underneath a raised tank, is not accessible for maintenance purposes.

flow figures decreased by 22%. Poor maintenance, as in Figure 2, can be exacerbated by poor installation (Figure 3). Instrumentation and automation equipment need to be accessible for maintenance purpose. If there are accessibility issues for practical (i.e. cannot be reached easily) and/or health and safety reasons, then the equipment simply will not get maintained and will eventually stop working.

The case studies presented above present barriers to the performance of the instrumentation systems because of (1) poor installation, (2) physical barriers where health and safety was not considered in the initial installation, and/or (3) poor operation and maintenance of the instrumentation assets. Such barriers lead to poor confidence in adoption of the systems that will generated the data to support digital transformation. The experience of these barriers has led to the development of the instrumentation life-cycle philosophy.

The instrumentation life-cycle

The instrumentation life–cycle has five stages. These are intended to take the designer and operator of instrumentation through the operational life of an instrument and highlight early on issues that could cause problems in the future. The first three stages of instrumentation life-cycle assessment are to help users think about the process of instrumentation and understand the value that an instrument brings. The five stages are illustrated in Figure 4, and detailed in the sections below.

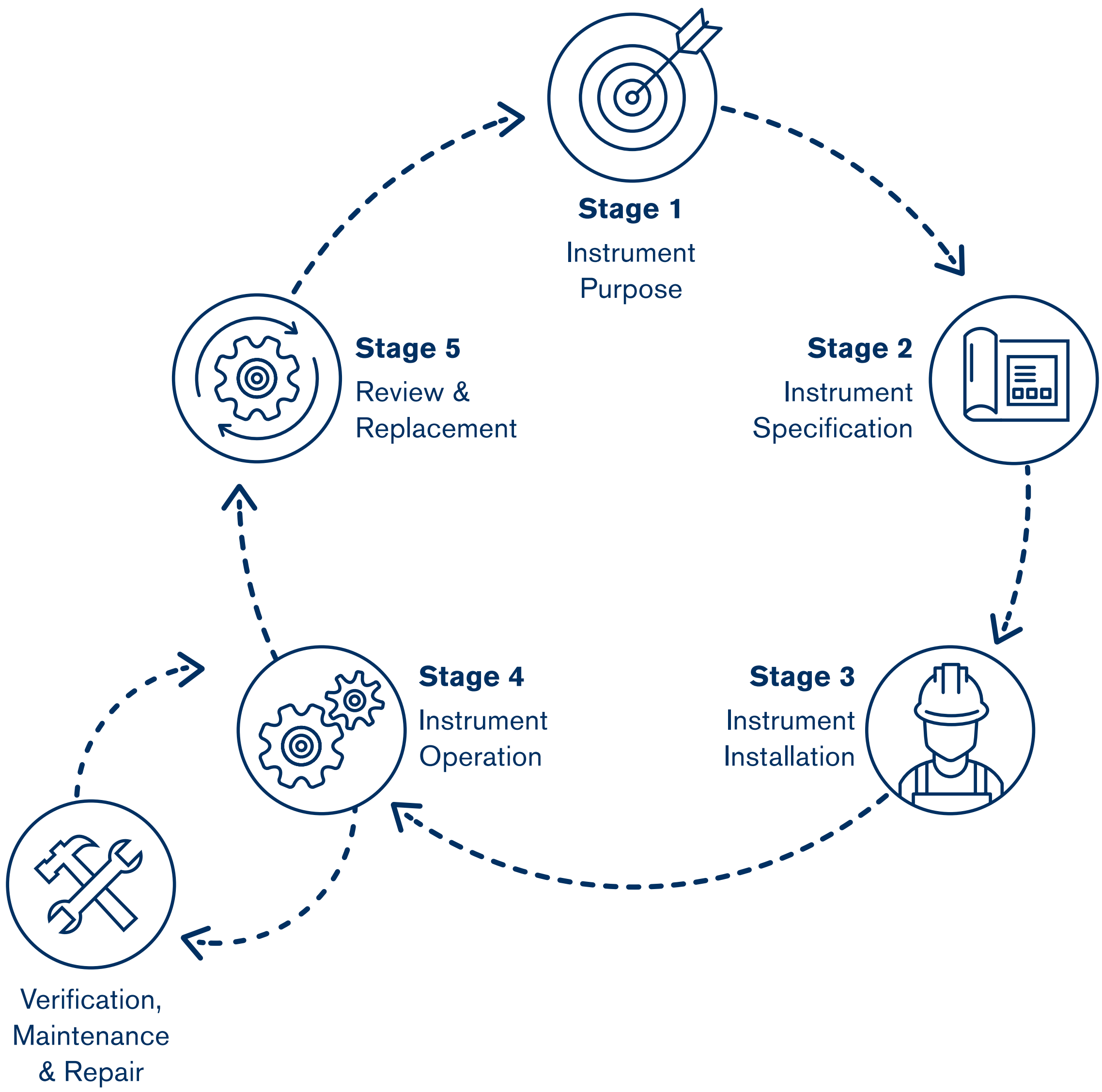

Figure 4: The five stage of the instrumentation life-cycle assessment

Stage 1 - Instrumentation Purpose

The first stage defines the purpose of an instrument in the water or wastewater system, the data it will produce and how this is going to satisfy an information strategy, thus addressing and clarifying the real application of the instrument. The reason why an instrument is needed could be multiple, including (but not limited to):

Regulatory

An instrument is sometimes required for legal purposes, under the operational legislation (for instance to ensure compliance with an environmental permit);

Financial

An instrument is required for financial purposes (for example for the billing of an industrial customer);

Monitoring/Alert purposes only

Some instruments could be in place for monitoring or alert purposes only. For example, a rotation sensor on a trickling filter or a settlement tank that will inform about a lack of rotation;

Asset Monitoring or Protection

Some sensors are installed on critical assets to ensure that their condition is monitored. The asset is therefore protected, and its state monitored to force the asset to stop in the event of a problem to prevent any damage. For example, this could be a vibration sensor on a centrifuge which can either report on its condition or stop it if there is undue vibration;

Control Purpose

An instrument or instrumentation system that is required to report upon the process variable for the control system to operate around a set point. For instance, a dissolved oxygen monitor opening and closing a control valve on an activated sludge plant to regulate the dissolved oxygen concentration.

Stage 2 – Instrument Specification

The second stage is the instrumentation specification and selection. For this, it is important to understand:

- What parameter is the instrument meant to measure (level, flow, temperature, state)?

- How is it meant to measure it? What technique is going to be used? What is the accuracy requirement? In what range it needs to operate? What is the required response time and measurement frequency?

- What is the application (e.g. in the network, on the inlet or outlet of the treatment works)?

- What are the physical constraints of the measurement location?
- What are the power and communication requirements?
- How is the instrument going to be operated and maintained?
- What are the sample conditioning requirements such as sample delivery, filtration and sample preparation and how is this going to affect the measurement?
- What are the costs involved in the purchase and the operation of the instrument (e.g. ongoing chemical cost and/ or ongoing consumable costs)?
- What are the legal limitations of installing the instrument? If some legal schemes are in place, the instrument may have to reflect this limitation.

The examples in this list, albeit not exhaustive, can have a significant impact on whether and how an instrument is installed.

Stage 3 – Instrument Installation

The third stage is to consider the instrument installation and how this is going to be achieved including ability to access, verify, calibrate, maintain, and replace the instrument itself. This is an iterative process, as an instrument may be ideal in terms of specification but not installation requirements.

Before installing any instrument, it is advisable that to be fully aware of the limitations of the technology as well as local conditions that may affect these limitations. These might be physical (e.g. a bend in a pipe or a control valve), chemical (an interfering substance within the water) or potentially biological (algal growth). Understanding these interferences and how they can change through time is essential to ensuring long-term instrument accuracy and reliability.

At this stage, it is also vitally important to understand how the instrument is going to be maintained and eventually replaced as a lack of maintenance (due to inappropriate installation) can affect the instrument's reliability. At the end of the instrumentation asset life, replacement will result in significant disruptions and cost implications. On the other hand, if future replacement is considered prior to installation, in the long run the cost of the instrument and its replacement can be significantly less. Therefore, putting together an operational maintenance and instrumentation replacement plan is worth the investment in time.

Stage 4 – Operation

The fourth stage is the operation and maintenance of an instrumentation system. This should include an operation and maintenance plan based upon the manufacturer's guidelines and adapted based on practical evidence including:

- Instrumentation cleaning frequency and methodology of how to achieve proper cleaning;
- Instrumentation end-to-end testing;
- Instrumentation calibration versus instrumentation primary verification;
- Instrumentation secondary verification techniques;
- Instrumentation consumables (chemicals, wipers, etc).

These will vary depending on the instrument type and location. There will be some fixed maintenance (such as chemical replacement) that must happen for the instrument to function, as well as occasional maintenance depending on performance. For example, electro-magnetic flow meter on a gravity inlet with chemical dosing in front of it requires significantly more maintenance than an electro-magnetic flow meter on a pumped final effluent line. The operation and maintenance phases are circular during the life of the asset and can be measured using primary and secondary verification to predict when an asset is likely to fail.

Calibration

Is the verification and adjustment of an instrumentation system against a traceable reference standard

Primary Verification

This is the test that an instrument is setup correctly and the instrument is working within design

Secondary Verification

This is the test that compares an onsite monitor to a traceable standard to ensure the measurement system is measuring correctly.

End to End Testing

This is a test that check that the transmission of the instrument signal is correct at the instrument end and the telemetry end. Faults are normally due to scaling issues

Stage 5 – Review & Replace

The fifth stage begins as the instrument is about to fail and comprises the review of its lifespan, its usefulness and whether and how it is replaced. The first part of the fifth stage is to review whether the instrument has achieved what was decided in the first stage and whether a replacement instrument is required. The purpose of the instrument may well dictate the outcome of this review. If the instrument is required for regulatory purposes then replacement is needed, whereas, if it is being used for redundant monitoring then its decommissioning is a better option. The main question to ask in this process is whether the replacement of the instrument is viable. If so, the instrument life-cycle starts all over again considering that the first stage has already been completed. Re-assessment of the second stage is needed to account for any technological improvements that have taken place in the life of the previous instrument. If the instrument has not achieved its purpose, its decommissioning should proceed. It is important to decommission an instrument as an abandoned instrument has the potential to lead to a lack of trust in instrumentation.

In summary, the instrument life-cycle is a tool that is used to ensure the accuracy of instrumentation. This is absolutely vital within the Digital Transformation concept as the majority of project have failed due to poor quality data. In fact, for instrumentation to be fully utilised, it is vital to take into account the instrumentation meta-data such as the instrument location, its purpose and uncertainty and how these will affect the decisions that are made in terms of regulation, control and asset management. These all contribute to the value of data and how it can be used to increase the effective use of instrumentation.

The effective use of instrumentation in Digital Transformation

What are the benefits of getting instrumentation right? Below are a few case studies of the effective use of instrumentation and how it can be used in Digital Transformation.

A simple view of the effective use of instrumentation in Digital Transformation

The first case (Figure 5) shows the flow data from a wastewater treatment works that has been converted to a total daily volume taken over several years. The instrument is a simple 100mm electro-magnetic flow meter that has been used for monitoring and regulatory purposes. Although the meter was not installed as part of a Digital Transformation project, the data produced can be used to improve performance.

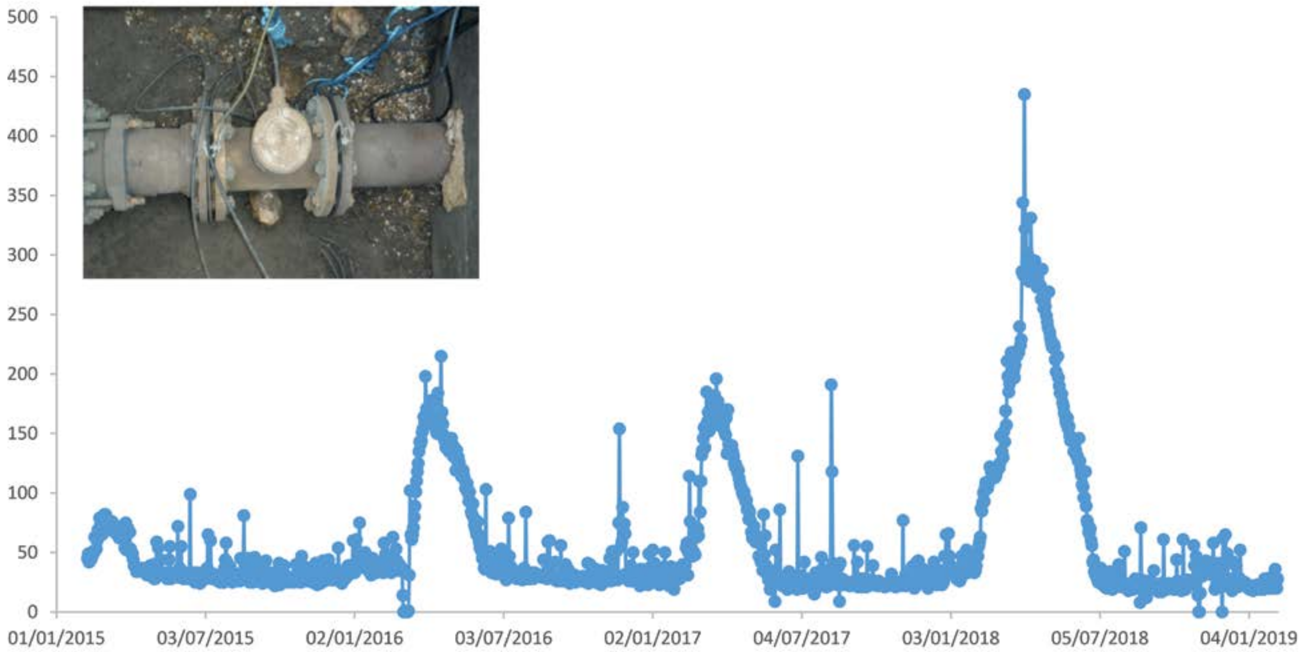

Figure 5: Flow data from a small rural sewage treatment works.

Figure 5 shows four clear peaks which grow over a period of three years showing the gradually worsening infiltration into the sewer environment. With additional information, such as rainfall, geology, and the performance of the system, this can be used to predict where the source of the problems within the sewer network is. This is a long-term asset planning scenario using total daily volumes, but even at a short-term operational time-scale, valuable information can be discerned from a simple flow meter. These include the performance of the flow control system and the works control of flow to full treatment or potential blockages within the wastewater system (collection network or the wastewater treatment works itself due to low flow events).

This example shows that the use of digital tools does not need to be complex. The global water industry is recognising this and as companies build their data and information strategy that maximises the value from the instrumentation they already have. In this case, Digital Transformation is not about installing more instruments, it is about getting the value out of the existing data sources, rationalising where necessary and only installing more instruments where there is a value identified.

A more complex view of the effective use of instrumentation in Digital Transformation

The common idea connected to Digital Transformation is that this is based upon a more complex model-based system fed by instrumentation working in real-time (similar to the Digital Twin approach). This is being seen in both the wastewater and potable sides of the water industry where the approach is being used for detection, and in some cases, control of non-revenue water.

In water distribution systems, the Digital Transformation approach has been in place for many decades. For instance, distribution systems have been using a systematic approach in creating a district metered area (DMA) and the subsequent flow monitoring of inputs and outputs to understand where the water is going. The big leap that water companies have taken is then using this data to drive their asset management programmes instead of replacing the oldest assets. An example of this is from Lisbon (amongst many other cities), where the operator used this approach to reduce the non-revenue water from 23.5% to 7.8% over an 8-year period, from 2005-2013 (Sardinha et al., 2017). The local water company for Lisbon, EPAL, used the flow data to identify water loss locations and then target asset replacement, resulting in a significant decrease in water loss from the system (Sardinha et al., 2017). There are many examples of reducing water loss and managing assets with more complexity such as using a digital twin, a model-based system complete with instrumentation inputs.

The wastewater collection system has also a wide variety of innovations that could be included under the general title of Digital Transformation. In the water network, these innovations mainly refer to the control of the hydraulic aspect of the system as this is the simplest component to control and has the highest impact on the customer and the environment. Similarly to water distribution systems, this actually started to happen long before the current trend of “Digital Transformation,” with smart wastewater collection networks first being installed in Minneapolis in the 1980’s along with systems in Europe, including the one that was developed for the Barcelona Olympics in 1992 (Kellagher & Osbourne, 2013). These systems have become more and more advanced but generally have worked with the basis of a model with inputs from weather service data and sewer level monitors. More developed countries have installed instrumentation within the network and have been controlling flows. However, the general reliability of these instruments within the sewer environment as well as the complexity of installation have been a barrier because of the harsh conditions within the sewer network, the difficulty of installation due to poor accessibility, the difficulty of installation due to a lack of power and telemetry sources as well as the difficulty of instrumentation maintenance.

There are also examples of technologies being successfully used within the wastewater network from basic to data analysis which has been later integrated into decision making. A prime example of this is the Eastney Project (Ellison, 2016) in Southern Water in the UK that used a combination of a wastewater collection network along with sewer level monitors, rain gauges and weather radar to predict the impact of flows into the wastewater system. The main driver for this project was to protect the city of Portsmouth from pluvial flooding of the sewer network following an incident in September 2000.

Conclusions

Instrumentation is a vital part of the Digital Transformation of the water industry. To overcome resistance to effective use, it must be as accurate as possible and uncertainty in measurements must be known. Fundamentally, it is important for companies to realise the value of instrumentation through the actual use of data and the corresponding information to drive (a) situation awareness and (b) informed decision making. This can be achieved through application in the short-term, but the full value is in setting a data and information strategy so that the instrumentation needs of the water operator can be identified. The instrumentation life-cycle can identify the best suited instrumentation and the value of data and information it produces.

References

International Water Association, (2019), https://iwa-network.org/projects/digital-water-programme/, last accessed 17 Sept 2020.

P Conjeos, 2020, A case study of the Digital Twin Approach taken with the city of Valencia, WEX Global 2020, 2nd March 2020, Valencia.

M Ellison, 2016, *Smart Flood Alleviation System Protects Portsmouth*, IET November 2016.

J Sardinha, F Serranito, A Donnelly, V Marmelo, P Saraiva, N Dias, R Guimarães, D, V Rocha, 2017, *Active Water Loss Control, EPAL Empresa Portuguesa das Águas Livres S.A.*

R Kellagher, M Osbourne, 2013, *The use of active system control when designing sewerage systems: a guide.* UKWIR, London

Acknowledgements

The author gratefully acknowledges insightful suggestions by Juan Antonio Baeza Labat, Katharine Cross and Samuela Guida. The author would also like to thank Vivian Langmaack for taking on the challenge of shaping the paper as it is visually.

INTERNATIONAL WATER ASSOCIATION
Export Building, 1st Floor
2 Clove Crescent
London E14 2BE
United Kingdom
Tel: +44 207 654 5500
Fax: +44 207 654 5555
E-mail: water@iwahq.org

Company registered in England
No.3597005
Registered Charity in England No.1076690

inspiring change

www.iwa-network.org