# Practical Application of Digital Twins in Water Supply Systems in São Paulo

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## SUMMARY

The amount of information available to water supply system operators has grown over the last few years, thanks to technological evolution and increased digitization levels.

This large volume of information, also known as dark data, can contain very useful information for operational control, and the sooner it is provided to operators, the more beneficial it will be. This type of information may be available to operators through reading and interpreting data from different sources, and/or even embedded in historical information.

Utilizing a computational platform that centralizes corporate information from different types of technologies can help owners gain insights to identify problems and optimize the system.

Bentley Systems' OpenFlows™ WaterSight®, which helps engineers create digital twins of water supply systems, was used in the practical application of digital twins in water supply systems in São Paulo. The application made it possible to integrate information, such as real-time and historical measurements from SCADA and historian; geospatial cadastral mapping of the network by GIS; monthly volumes consumed by each customer; and hydraulic model.

Uniting and centralizing the information from each data source made it possible to configure the platform to extract important information about system operation: water balance indices, rules for detecting anomalous events, and operational dashboards.


## INTRODUCTION

This project presents a case study conducted at Sabesp involving the application of a cloud platform for digital twins of water supply networks.

A digital twin is a digital representation of a physical asset, process or system, built through integrating information from multiple corporate data sources. A digital twin can be applied to any phase of the asset lifecycle, ranging from the planning phase, through design and construction, all the way through to operation and maintenance.

To create a digital twin for this system operation, the project team integrated field operation data sources (flows, pressures, and tank levels), information on monthly consumption volumes for each consumer unit, geographic information system (GIS) cadastral data and hydraulic network modeling.

The team replicated measurement data from field remotes, available in a proprietary communication management system, to the company's historian system, which stores historical measurements in reservoirs, pumping stations, macro-meters, pressure-reducing valves and pressures at critical points in the system.

A digital twin enables corporate data from different departments/areas to be centralized and integrated. This helps secure qualitative and quantitative analysis of (remote) field sensor performance; identify equipment failures in the field; detect pressure anomalies at critical points in the system and network leaks; analyze water balance by district of measurement and control (DMC); identify inconsistencies in the limits of DMCs recorded in the corporate GIS system; confirm measurement failures that, if discovered too late, would impact the calculation of the water balance and would lead to a misinterpretation of the results presented; analyze pumping systems' energy performance; and simulate real-time hydraulics, operational forecasting, and emergency response planning support.

## METHODOLOGY USED

The project team chose supply sectors as the target of the platform implementation that already had their linear assets, field sensors in operation with historical measurements logged in the database, a hydraulic model of the distribution network, and information on monthly customer billing recorded in the GIS. They selected the sectors based on the prospects of using the platform to monitor the system through real-time data, automated operational analyses, and agile support for decision-making.

Once they selected the sectors, they defined the information technology architecture with multidiscipline teams to establish a standardized implementation.

Creating the digital twin, specifically when integrating operational data, involved gathering information on flow measurements, pressure, reservoir levels, and equipment status, both for the water supply system and for distributing water in the sectors.

By integrating the SCADA supervisory system and its historian databases, Sabesp was able to input historical measurement records in near real time into a digital twin to maintain a frequent cycle of computational analyses to determine measurement standard performance. Another integrated database is the commercial system, which links measurements of monthly volume billed for each system branch into a digital twin, which, when linked with data from the GIS, enables automated calculation of the performance indexes of each DMC.

With a view to detecting anomalous events in the system's operation, mechanisms were created for its rule-based automation. These rules work as triggers that, once activated, alert the operator so that they can anticipate the incident or verify any problems in the field more quickly.

These triggers can be created because of data measured against its absolute value, or against its historical pattern observed in recent months. The trigger can be referenced to a measurement or a combination of measurements, enabling the ability to create complex operational rules.

The performance pattern analyzed is defined through machine learning algorithms that clean the historical data collected and determine upper and lower value ranges, creating confidence intervals, illustrated by the gray areas in Figure 1.

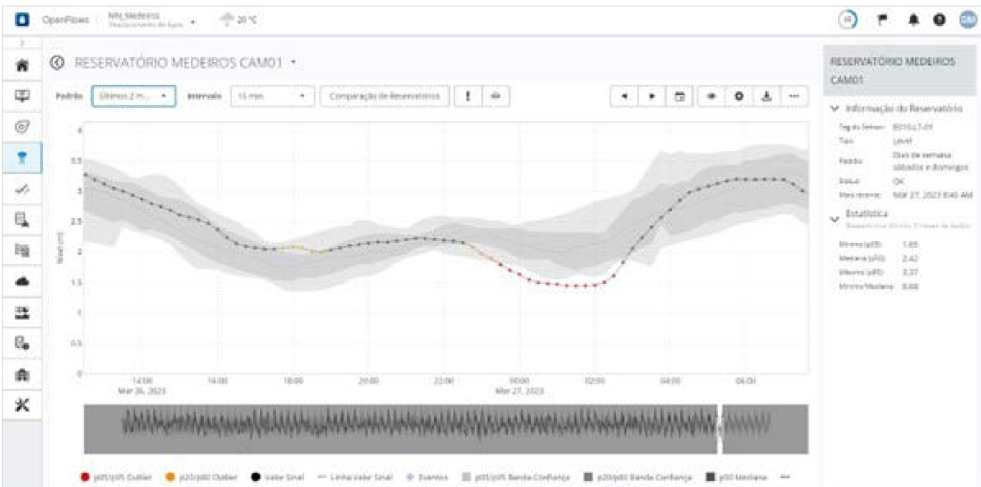


*Figure 1: Reservoir level measurement with integrated pattern analysis.*

The intervals are defined using the 20th and 80th percentiles (dark gray) and the fifth and 95th percentiles (light gray), the values of which are calculated for different historical periods ranging from one to 12 months. The measurements are color coded to help identify the performance of the measurement based on its standard. Red dots are used for measurements above or below the confidence band of the fifth and 95th percentiles, and yellow dots are used when they are outside the confidence band of the 20th and 80th percentiles.

Pattern-based alert triggers are used to detect anomalous behavior based on the value of the measurement against the historical standard. The ability to create combined triggers enables a high range of operational situations that can be represented to detect problematic situations.

To use the practical example of a combined trigger, which supports the detection of an anomalous pressure drop problem in each DMC controlled by a pressure-reducing valve (PRV), this is the combined analysis of flow measurement, pressure measurement downstream of the PRV and at its critical point.

This combination of triggers provides a more accurate analysis of failure events alerted by the system. If the pressure at the critical point falls below the value defined in the parameter and the downstream pressure and the flow rate are simultaneously below their standard performance, the system will not issue an alert, since the combined condition has not been met, i.e., it may have experienced a pressure variation at the critical point in a given time interval during valve closure, as shown in Figure 2. Combined measurements are also referenced to a minimum duration of consecutive measurements where the stated conditions are validated, such as 30 minutes or more.

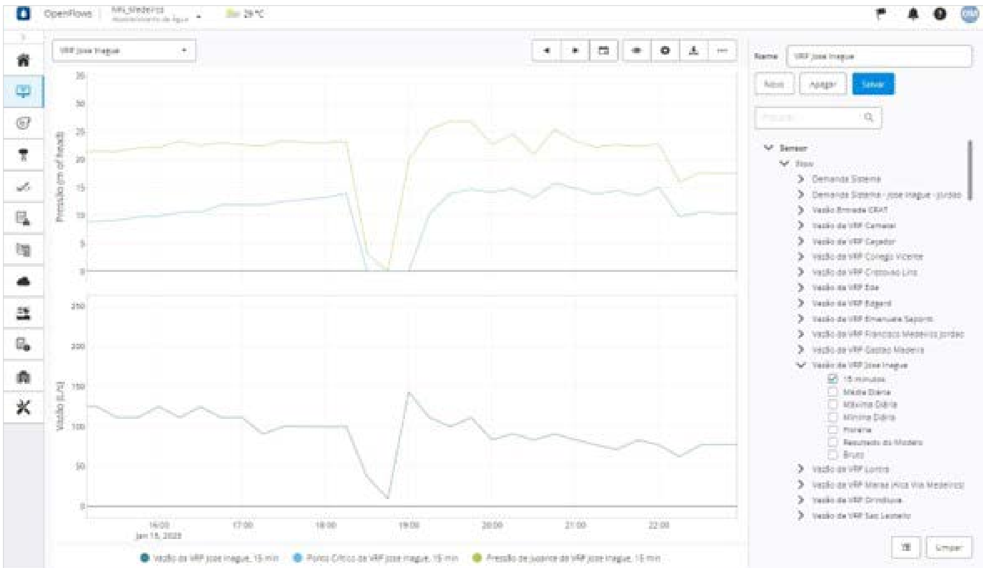

*Figure 2: Flow and pressure measurement performance after closing a PRV.*

This combination of conditions helps to avoid triggering pressure-drop events caused by PRV closure, which may cause a reduction in downstream pressure and flow rate. Such situations can also cause a pressure deficit at the critical point but that is to be expected.

Other operational events that were also monitored include: communication problems between the field equipment and its data recording in the database, verified through triggers that analyze a period of lacking data transmission; and problems in recording data through constant reading detection triggers, also known as flat readings.

Problems and insights raised by the platform were evaluated through regular meetings with the operational and engineering teams of the units responsible for supplying the selected sectors.

## RESULTS OBTAINED

Once they built a digital twin, and it became operational, it was possible to collect historical data for a period of 24 months, which enabled performance standards and data prediction to be analyzed through machine learning algorithms and statistical analysis.

Once Sabesp defined the patterns, operational rules were configured for automated monitoring of the sectors to detect problems in the system in a more reliable, automated way, as detailed above. The configured rules helped operations to detect the following types of operational problems:

- Data logging failure in historian
- Logger failure (equipment that records pressure and flow data)
- Operational failure of PRVs
- Network leaks and ruptures in certain zones and DMAs
- Abnormal pressure drop at critical points of DMAs

As the platform gathered information from different data sources, these types of problems were observed more slowly, as operators had to access various software, which slowed down field data analysis. Centralizing information in a single environment simplified access to data by the operator and gathered previously unknown information, such as the study of the standard measurement performance. Thanks to automated detection of anomalous events and hydraulic calculations, these problems are reported immediately, whereas, when compared to the period before using a digital twin, some problems would be manually detected by operators after the final impact on the customer, which would be hours or even days slower compared to a digital twin's application.

Parameterizing and adding new triggers to detect anomalous events can be revisited whenever necessary, adjusting the needs of the operation or dynamism of the supply system itself.

The image below shows an example of an event detected relating to an operational problem in a PRV where its downstream pressure was below the pattern, highlighted in the light blue area of the graph, causing low pressures in the DMA.

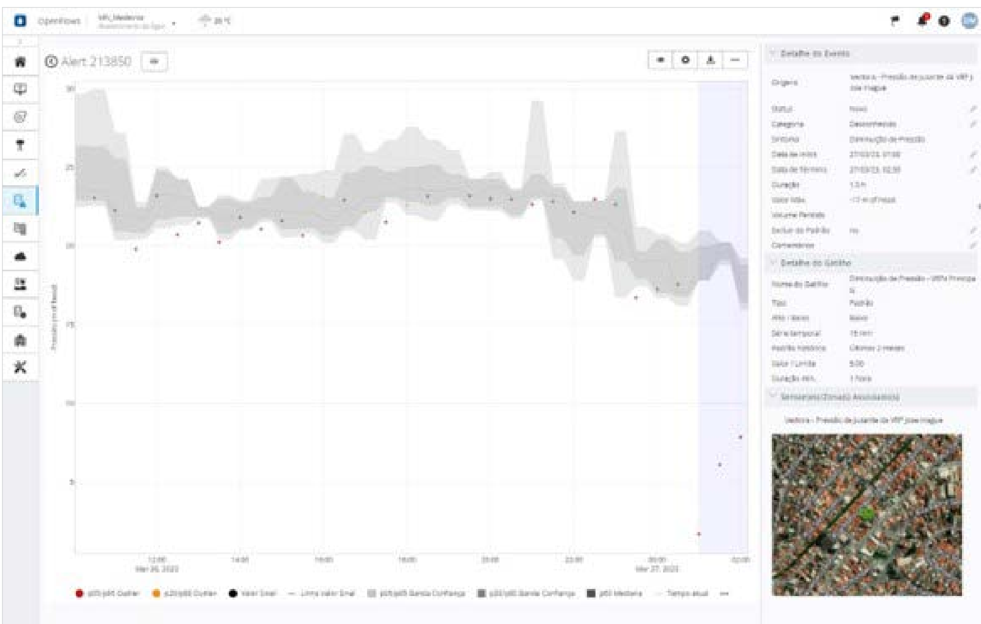


*Figure 3: Example of anomalous event detected – downstream pressure below pattern.*

Another new piece of information provided to operators as a result of creating a digital twin was the water indexes calculated from linking data from the historian, the commercial system and the GIS. Based on this combination, the water balance of each DMA in the chosen sectors was automated, allowing the analysis of water performance indices to prioritize interventions and other initiative-taking actions to control losses. This evaluation also supported the study of the records that delimit each area and its cadastral polygon. The platform directly helped to detect a problem in a DMA that experienced a monthly consumption volume that was greater than the distributed volume.


*Figure 4: Water balance reported with consumption billed volume greater that distributed.*

As the platform analyzes the balance with the integration of macro-meter values and links this with geospatial information on consumers and bordering polygons, this fact could be verified right from the start.

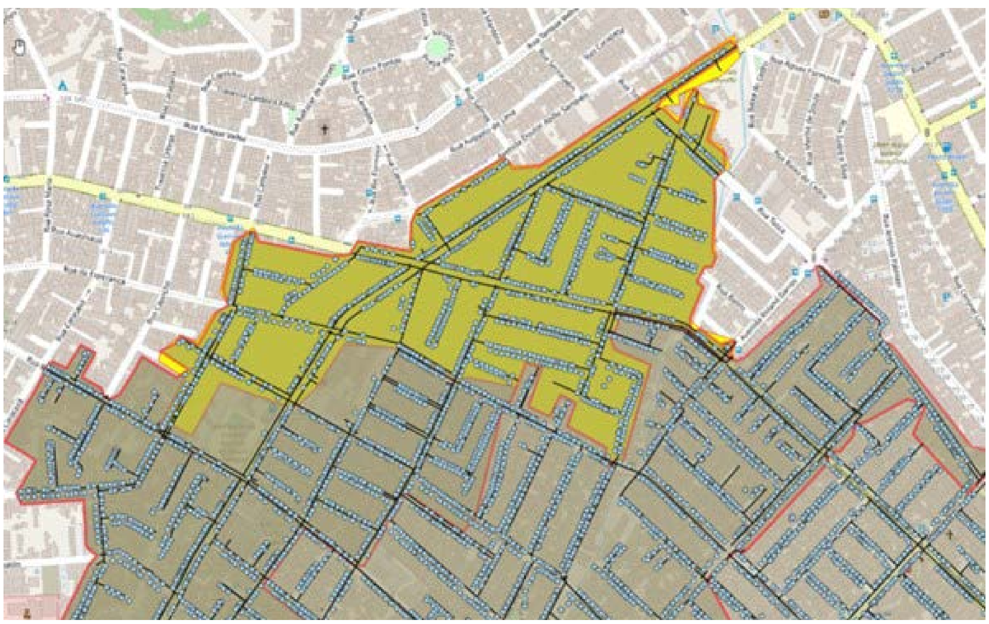

*Figure 5: Geospatial cadastral recording of consumers and the polygonal limit of the DMA.*

The anomaly could be analyzed by the field team, who found a cadastral problem in one of the sections that borders an adjacent DMA that was improperly opened, causing lower-than-expected values in distributed volume.

When using the platform and through its generated alerts, we were able to identify aspects that would be difficult to spot without the use of a data integrator platform equipped with automated tools, such as:

- Field meter parametrization that was incompatible with the configuration made in the equipment management system, causing inaccuracy in the measured values.
- Consistency in the recording of DMAs.
- Performance of field data transmission.
- Comparative analysis of different measured quantities.

## CONCLUSION

Advances can be seen in the availability of technologies that generate data for monitoring the supply system, which means that companies have much greater volumes of data than they are able to use and, consequently, they need a way to manage and automate data analysis.

In this scenario, implementing a supply management system that integrates data from these technologies and extracts relevant information becomes vital to making the most of the acquired data, resulting in more efficient services.

The platform provided the operator with a simple way to access information from different data sources that were previously accessed through separate environments. Combining these sources provided the extraction of information that was previously collected indirectly through manual procedures, such as loss index analysis, analysis of minimum night flow rate, and search factor and available volumes.

Some of this information collected by the platform was not available before creating a digital twin, such as the determination of the standard performance of measurements, extracted from computational calculations on the information collected from the company's historian. Making this information available through visual reports allowed operators to easily observe situations where a measurement was outside the parameters of normal performance. Based on this new information, they were able to establish operational rules to receive notifications for anomalous events, based on the default performance, or absolute value limits, of one or multiple combined measurements.

Operators therefore obtained faster reading and interpretation of operational information, accelerating decision-making procedures, such as identifying an anomalous event and quickly interpretating the cause through these smart triggers. When using a digital twin, Sabesp was notified of anomalous problems one to two hours after the onset of the change in performance for the operational rule. Prior to using a digital twin, problems were detected entirely through customer complaints and/or by manual and initiative-taking analysis by operators, looking at separate systems.

The platform also identified chronic problems that were not visible to operators, such as the identification of inconsistent cadastral information on DMA borders, and the detection of faulty meters in the equipment.

It is important to emphasize that implementing a platform of this nature requires prerequisites that depend on the system's level of digitization maturity, namely digitization of linear assets (GIS), field sensing in the main assets, and safe and agile communication and storage infrastructures. It is therefore recommended that companies interested in adopting this type of platform conduct a critical analysis, considering the prerequisites and their needs in view of the desired objectives.

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