Article

An Information Systems for Infrastructure Asset Management Tailored to Portuguese Water Utilities: Platform Conceptualization and A Prototype Demonstration

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Abstract: This paper presents a new information technology platform specially tailored for infrastructure asset management of urban water systems operated by water utilities of lower digital maturity level, developed in the scope of DECIdE research project. This platform aims at the integration of different data from the water utilities with several information systems and the assessment of the system performance, in terms of water losses, energy efficiency and quality of service by using developed tools (i.e., water and energy balances and key performance indicators). This platform was tested with data from five small to medium size Portuguese water utilities with different maturity levels in terms of technological and human resources. Obtained results are very promising since the platform allows to assess the systems performance periodically which constitute an important part of the infrastructure asset management for small and medium-sized water utilities

Keywords: Data integration; Decision Support System; Information Systems; Infrastructure Asset Management; Water supply systems

1. Introduction

Most water supply systems (WSS) in Portugal were built during the first half of the 20th century. For several decades, the main concern of water utilities was the increase of water service coverage, as reflected in the first Strategic Plan for Water Supply and Wastewater Treatment in Portugal 2000-2006 (PEAASAR). Currently, water service coverage in Portugal is higher than 95%, thus the paradigm of building new or expanding the existing WSS has changed to the rehabilitation of the most deteriorated assets and implementing rehabilitation rates that allow maintaining the system at an acceptable to good infrastructure value index.

The responsibility for provision of water supply services is shared between the Portuguese state, through the public holding company Águas de Portugal and its subsidiaries, and the municipalities. The state is responsible for managing the multi-municipal systems (i.e., the bulk water systems), whilst municipalities are responsible for the municipal systems (i.e., the distribution networks). Thus, the 308 municipalities manage their WSS either directly or indirectly through concessions. According to the Portuguese Water and Waste Services Regulation Authority (ERSAR), these municipal water utilities have 126 surface water abstractions, 5,049 groundwater abstractions, 104 water treatment plants, 3,078 other treatment facilities, 587 chlorination stations, 1,798 pumping stations, 7,277 water tanks, and 109,433 km of pipes [1]. This huge number of assets needs to be managed

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in an efficient and effective manner in order to guarantee the infrastructure long term sustainability.

Urban water infrastructure asset management (IAM) is essential for water utilities to efficiently manage their large variety of physical assets [2,3]. In Portugal, the national regulatory authority, ERSAR, recommends the application of the IAM methodology described by [2] in WSS that supply over 30,000 users. The IAM methodology requires the use of different tools for the assessment of the WSS performance in terms of water losses, energy efficiency, rehabilitation needs, and pipe failure rate, amongst others. These tools include water and energy balances calculation, system performance assessment, hydraulic modelling, as well as complex Artificial Intelligence (AI) techniques to predict demand and locate anomalous events. Additionally, IAM requires knowledge on the assets condition so that rehabilitation plans can be developed. This knowledge is provided by data that are collected and stored in different databases, generally spread in several departments or divisions of the water utility. Thus, the IAM manager has a hard task every time he needs to assess the system performance, since data must be collected from different departments within the water utility in a coordinated procedure [4].

Reliable data are the basis of effective and efficient IAM implementation. Several information systems (IS) are typically used to produce, transform, manipulate, and analyze the desired information. The most widely used IS by water utilities are geographic information system (GIS), customer relationship management (CRM), customer information system (CIS), enterprise resource planning system (ERP), and supervisory control and data acquisition system (SCADA), computerized maintenance management system (CMMS), laboratory information management system (LIMS), among others [5].

The management of this information is of the utmost importance for water utilities for the daily control, operation, management, and planning of their activities. Since water utilities face the challenge of planning infrastructure interventions for a huge number of assets, IAM software is becoming more prevalent as a strategic planning tool, providing critical information on capital assets and timing of investments to the decision-makers. This type of tool should integrate datasets from different IS, including GIS, CMMS, work orders, and field data from SCADA, as well hydraulic modelling [6]. However, integrating the several, often conflicting, sources of information available on the infrastructure, including asset condition, system performance, and the various predictive analyses that assist in prioritizing projects or interventions is a major challenge to asset managers, particularly, in water utilities with a lower technological maturity level [7,8].

Several solutions [8–11] have been developed to solve the data integration and analytics problem in water utilities. The development of the proposed solution may start within the utility itself, which has the necessary human, financial and technological resources to develop a system tailored to their needs, or through the acquisition of a commercial software solution. In many utilities, the lack of human resources and their vulnerability to commercial pressures are often the basis for reactively acquiring solutions (e.g. miraculous software packages that solve all the WSS problems) and, thus, lacking long-term planning for the use of the acquired software [5]. As such, the complete IS capabilities are usually not fully explored since they are acquired due to just a set of functionalities. Rather than having a scattered set of technological tools that meet specific functions, it is essential to consider and integrate each IS as a key element for IAM.

The solution implemented to integrate datasets from IS of small to medium-sized water utilities and to support decision-making on WSS was a platform developed in straight collaboration with water utilities to answer their current needs and concerns. In order to be an inclusive platform both simple and complex analysis can be carried out depending on available data. This paper aims to share with the scientific community the main difficulties and main learnings with the implementation of this tool as well as means of overcoming performance analysis with short and unavailable data.

This research was funded by the Portuguese national Funding Agency for Science and Technology (FCT), under DECIdE project, lasted for 18-months, and included five

 doi:10.20944/preprints202211.0295.v1

Portuguese water utilities with different technological maturity levels. The main functionalities are demonstrated using two case studies from water utilities with different technological maturity levels, discussing the limitations of the analysis in each case.

2. Platform prototyping

2.1. Requirements analysis

The analysis of the platform prototype requirements was carried out with the deep involvement of end-users to analyze their expectations and to define software functionalities (i.e., capabilities, usability, inputs, and outputs). A workshop was held at the beginning of the project, with the participation of the research institutions and the five water utilities (i.e., end-users). The main requirement was that the platform should be able to integrate data that are already collected and to allow the automatic calculation of a set of performance indicators relevant to IAM and, also, required for the annual reporting to the water and wastewater authority (ERSAR). These performance indicators require specific data for computation, including metered water volumes, system characteristics and financial data, amongst others. A set of 16 performance indicators was considered for implementation in the platform (see Table 1). These performance indicators are grouped in four main objectives (infrastructural, environmental, economic sustainability and quality of service) and can be used to assess the performance of the system as a whole, or at subsystems or district metering area (DMA) levels; the performance assessment results can be compared at the subsystem or DMA level, in order to develop rehabilitation or intervention plans.

Table 1. Set of performance indicators identified by the utilities for implementation in the platform.

Objective	Performance indicator	Units
Infrastructural sustainability	Network rehabilitation	[% / year]
	Infrastructure value index (IVI)	[-]
	Pipe failure	[# / (100 km. year)]
	Service connection failure	[# / (1000 service connections. year)]
Environmental sustainability	Real water losses in the network	[m^3 / (km . year)]
	Real water losses in service connections	[liters/(service connection . day)]
	Energy efficiency of pumping installations	[kWh/(m^3 . 100 m)]
	Energy in excess per unit of input volume	[kWh/m^3]
	Energy in excess per unit of the revenue water	[kWh/m^3]
	Ratio of the total energy in excess	[-]
Economical sustainability	Unmetered consumption	[%]
	Non-revenue water	[%]
	Real water losses	[%]
	Treated water volume capacity	[days]
Quality of service	Disruption caused by pipe failures	[hour / (100 users. year)]
	Disruption caused by service connection failures	[hour / (100 users. year)]

The calculation of some performance indicators required the implementation of additional tools. Two of these tools are the water and the energy balances. The implemented

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water balance (Table 2) follows Alegre et al. [12] approach. The energy balance (Table 3) proposed by Mamade et al. [13], was integrated in the platform, with two different approaches according to available data: 1) a simplified version, which requires minimum data and no hydraulic simulation, provides a global overview of the main components of energy consumption in the system and can be used at the subsystem or DMA level; and 2) a complete assessment that requires a calibrated hydraulic model of the network and provides a detailed assessment of energy consumption in each balance component.

Table 2. Water balance [12].

<table>
<tr><td rowspan="8">System input volume</td><td rowspan="2">Authorized consumption</td><td>Billed authorized consumption</td><td>Billed metered consumption</td><td rowspan="2">Revenue water</td></tr>
<tr><td>Unbilled authorized consumption</td><td>Billed unmetered consumption</td></tr>
<tr><td rowspan="6">Water losses</td><td rowspan="3">Apparent losses</td><td>Unbilled metered consumption</td><td rowspan="6">Non-revenue water</td></tr>
<tr><td>Unbilled unmetered consumption</td></tr>
<tr><td>Customer meter inaccuracies</td></tr>
<tr><td rowspan="3">Real losses</td><td>Leakage on distribution pipes</td></tr>
<tr><td>Leakage and overflow at storage tanks</td></tr>
<tr><td>Leakage on service connections up to point of customer meter</td></tr>
</table>

Another relevant tool is the capital cost calculation tool, necessary for the computation of the infrastructure value index (IVI). IVI is the ratio between the current (fair) value of infrastructure and the replacement cost on a modern equivalent asset basis. IVI can be calculated following an asset-oriented or a system-oriented approaches [14]. IVI calculation in the asset-oriented approach is based on the useful life of each asset, on depreciation curves, and on replacement costs for each type of asset, whereas, in the service-oriented approach, IVI calculation is based on the performance of functional units of the infrastructure [15].

The data needed to compute the performance indicators depicted in Table 1 are of different nature, namely, geographical, and physical data (e.g., identification, type, location, dimensions, material), operational and maintenance (e.g., dates, location), and billing and accounting (e.g., revenue, replacement costs). Thus, a characterization of the information systems existing in the five water utilities was carried out [4]. This characterization allowed a better understanding of the technological maturity level of each utility, as well as of existing data standards and workflow processes. In summary, this characterization showed that:

1. The use of GIS is generalized, although with different implementation degrees.
2. The use of ERP and CRM systems to manage and store commercial and accounting data is generalized.

3. Only two water utilities use an IS to store Service Work Orders. The remaining utilities still use paper records to register and store this type of data.
4. The use of SCADA systems is not generalized and is mostly used to monitor the input water volumes or flow rates of their systems.

Table 3. Energy balance [13].

<table>
<tr><td rowspan="5">Natural input energy</td><td rowspan="13">Total system energy input</td><td rowspan="7">Energy associated with authorized consumption</td><td rowspan="2">Energy associated with water supplied to consumers</td><td>Minimum required energy</td></tr>
<tr><td>Supply energy</td></tr>
<tr><td rowspan="4">Dissipated energy</td><td>Pipe friction</td></tr>
<tr><td>Valve head losses</td></tr>
<tr><td>Pumping stations' inefficiency</td></tr>
<tr><td rowspan="8">Shaft input energy</td><td>Hydropower plants' inefficiency</td></tr>
<tr><td rowspan="2">Recovered energy</td><td>Associated with authorized consumption</td></tr>
<tr><td rowspan="6">Energy associated with water losses</td><td>Associated with water losses</td></tr>
<tr><td colspan="2">Dissipated energy in nodes with water losses</td></tr>
<tr><td rowspan="4">Dissipated energy</td><td>Pipe friction</td></tr>
<tr><td>Valve head losses</td></tr>
<tr><td>Pumping stations' inefficiency</td></tr>
<tr><td>Hydropower plants' inefficiency</td></tr>
</table>

2.2. Platform conceptualization and architecture

Integrating data and information from several utilities is a challenging task since utilities have distinct technological maturity levels and workflows. The developed prototype platform had to meet the technological limitations or advances of each participating water utilities, and to overcome the challenges of how to integrate the required data from different IS, data model structures and ontologies into a common platform for all water utilities. The platform had also been developed aiming at the integration of real-time data from sensors installed in water distribution networks, such as pressure and flowrate, which need to be stored in adequate database solutions. A potential future use for these time series can be in the detection and location of anomalous events (e.g., pipe burst) using AI techniques namely, machine learning, deep learning, and optimization algorithms.

A web-based application on cloud services was chosen as the most adequate platform architecture, since it allows universal availability using web-connected devices, as no further requirement than a web browser is needed to use the platform, as well as easier maintenance and updates by the platform development. The platform was implemented using Django, a free and open-source Python Web framework, to obtain a fast-developed, scalable, and secure platform. The client application on the frontend of the framework

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uses the D3 JS library and Bokeh. These solutions offer a wide range of possibilities to define the specific visualization that was needed to represent the water and energy balances as well as the dashboard components to represent the performance indicators. An application programming interface (API) was developed to provide access to the database by the frontend application. Additionally, the platform offers a set of directly accessible services as the API may be consulted by other applications if authenticated. Docker technology was used for developing, shipping, and running several applications (i.e., API, frontend, and database). Two Docker containers were created: the first container comprises the frontend and backend applications whilst the second container includes the Database Management System (DBMS) and the database. Thus, it is possible to independently update the frontend or backend application and database.

Figure 1 shows the flow of platform usage. Initially, the platform database has no data. The first step in the use of the platform is the import of raw data files from the existing information sources. To this end, existing information is uploaded to the data integration module by the user (1). After file importing and parsing, data are inserted in the platform database (2). The performance assessment functionalities access the necessary data (in the database) through queries using the provided API which, in turn, returns the necessary data (3). Once the assessment is carried, a report is provided to the user with the obtained results (4).

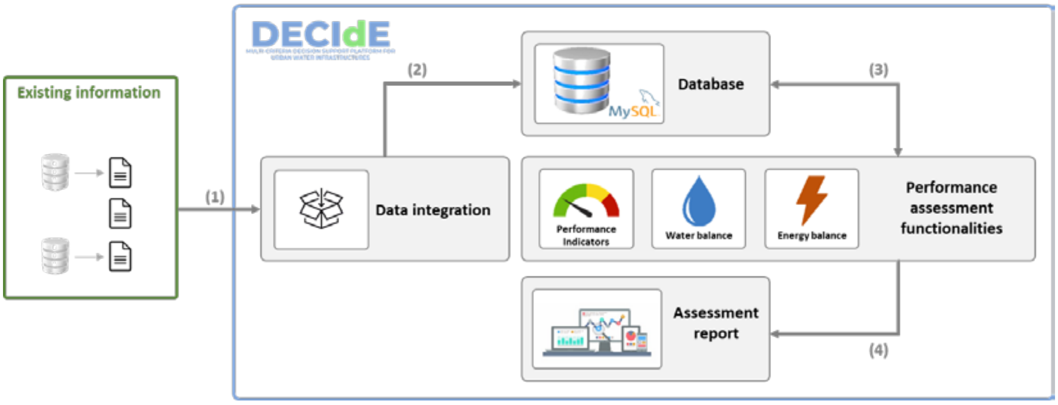

Figure 1. Flow of requests according to the platform architecture.

2.3. Data modelling and import

The different technological maturity levels of the participating water utilities are greatly reflected in the IS used and the available data. Therefore, the first challenge to overcome was to design a domain model that could represent all the necessary concepts for performance assessment based on the available data of the different utilities. Due to the heterogeneity of IS and data models used by those utilities, an ontology-based domain-driven-design was followed.

Table 4 presents the designed domain model with the required attributes to import the different types of assets considered. MySQL was selected as a DBMS solution being its efficiency studied in a later stage due to the short duration of the project and the lack of human resources. Although this solution may be adequate for the aim of the project, it may not be the best solution in the medium to long term due to the expected increase in the amount of data (in particular the real-time data from the sensors). In this case, other types of database technology may be more efficient, such as document-oriented databases, graph databases, or even hybrid solutions. Nonetheless, the study on the efficiency of distinct DBMS solutions is out of the scope of this paper.

The platform supports the upload of incomplete data (i.e., missing fields in files due to confidential data and fields with incorrect records), though limiting the platform outcomes. Furthermore, the data model is prepared to maintain a history of the infrastructure

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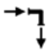
and other time-dependent data. When updating such data, the previous record is time-stamped and kept in the database, allowing to analyze its evolution.

Table 4. Designed domain driven model.

Symbol	Asset	Attribute	Symbol	Asset	Attribute
	Subsystem	- Unique identifier - Description		Storage Tank	- Unique identifier - Description - Subsystem identifier
	District Metered Area	- Unique identifier - Description - Subsystem identifier		Storage Cell	- Unique identifier - Description - Storage tank identifier - Storage capacity - Elevation - Water level
	Delivery point	- Unique identifier - Description - Subsystem identifier - DMA identifier - Elevation - Service pressure		Pipe	- Unique identifier - Subsystem identifier - DMA identifier - Length - Diameter - Material - Installation date
	Water abstraction	- Unique identifier - Description - Subsystem identifier - Hydraulic head - Water level		Service connection	- Unique identifier - Subsystem identifier - DMA identifier - Length - Diameter - Material - Installation date
	Pumping Station	- Unique identifier - Description - Subsystem identifier		Water meter	- Unique identifier - Subsystem identifier - DMA identifier - Status - Type of use
	Pump	- Unique identifier - Description - Subsystem identifier		Service work order	- Unique identifier - Subsystem identifier - DMA identifier - Affected asset identification

- Hydraulic head		- Cause - Type of intervention - Intervention extension - Intervention date - Date and time of service disruption - Date and time of service reestablishment

The platform supports the upload of incomplete data (i.e., missing fields in files due to confidential data and fields with incorrect records), though limiting the platform outcomes. Furthermore, the data model is prepared to maintain a history of the infrastructure and other time-dependent data. When updating such data, the previous record is time-stamped and kept in the database, allowing to analyze its evolution.

Two options were considered to import and update data into the platform: 1) automatic connection to the IS databases and 2) using a raw submission file import module. Ideally, the platform should directly connect through a web service to each IS to collect the data to be integrated. This option would lead to a better platform usability, as data are periodically and automatically uploaded and hence updated. Nonetheless, this requires an initial setup and regular maintenance to be carried by a utility's IT specialist. Additionally, the General Data Protection Regulation (GDPR) may impose some restrictions regarding the access of third-party software (such as the platform) to sensitive data. It was concluded that remote database access solutions could not be adopted in the short term due to the unavailability of utility IT specialists in most utilities. As such, a compromised solution based on a raw data file submission and data integration module was considered and implemented, since it is comprehensive and allows the platform to be used by all utilities. A common interface was developed to parse the uploaded files, by identifying the related data model elements, tables, and formats to target.

During the file submission for data integration, an initial mapping is needed between data model elements and file content attributes. Additionally, and for some data model elements, a second mapping is required between the considered options in the specific data model element and the file content attribute. For instance, the meter status is considered as "1" for active status in the database of the platform. However, the file content can have a different record such as "On", "Active" or "In Service".

Measurements can be assigned once the infrastructural elements have been imported. In most utilities, the billing system is the most common way to obtain water consumption measurement, which in the best-case scenario is recorded monthly. Once meters associated with the billing are imported, aggregated monthly measurements can be associated with some assets (e.g., storage tanks, abstractions, pumping stations, delivery points). It is assumed that aggregated volumes were validated by a validation process. A template spreadsheet can be downloaded from the platform by selecting the period and the type of infrastructure measurements to upload or to update. After filling the measurements in the template spreadsheet, they should be uploaded to the platform. In a second phase, it is expected to include a model to automatically validate and generate aggregated volumes from SCADA records. Additionally, some additional data may be manually inserted for complementary information, such as the reference elevation in the simplified energy balance.

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2.3. *Implemented assessments*

Three modules for carrying out the assessment analysis for a user-defined period (e.g., 12 months) were developed: the performance assessment; the water balance; and the energy balance. Sectoral analysis at the subsystem level is also possible, allowing the comparison of results between subsystems. The platform includes different types of information representation, namely, pie, bar and bullet charts and tabular forms. This information can be exported as an image in PNG file format to be included in reports.

The water balance was implemented according to the IWA standard methodology as described in Section 2. Most Portuguese water utilities do not have hydraulic models, thus, at this stage, only the simplified version of the energy balance was implemented.

The water and energy balances modules allow the assessment of water and energy consumptions along the system, contributing to reducing water losses and energy costs. These balances rely on different data (e.g., input volumes and energy consumption, billed and unbilled consumptions, elevations), which are usually spread over several IS. If these balances are calculated for network sectors, the complexity of data collection and management carried by the utility manager can be overwhelming. As such, and upon the selection of a given area of analysis in a defined period, the required data for the balances are prepared by querying the database. For the chosen period, the assets within the area of analysis are collected, and the respective measurements are summed to provide the total volumes. The user should validate and may change calculated/suggested input values.

From the 16 performance indicators presented in Table 1, the infrastructure value index was not implemented. The main reason for this decision was the difficulty to collect the financial data to determine the current value of infrastructure and the replacement cost on a modern equivalent asset basis. So, the performance assessment module incorporates 15 of the referred 16 indicators. Associated with the water and energy balances, some additional performance indicators were included (e.g., CO_2 gas emissions due to pumping stations, measured as ton of CO_2 equivalent).

The graphical visualization of these performance indicators was challenging, especially for allowing the comparison between areas of analysis. As such, a dashboard was developed in which the user may select the single or multiple areas to analyze (e.g., subsystems or DMAs) as well as the period of analysis. The required data to calculate all the performance indicators are automatically fetched from the database and each indicator is presented in a customized chart, in which different filters and types of representation may be applied. Figure 2 shows the graphical user interface (GUI) for the data import module.

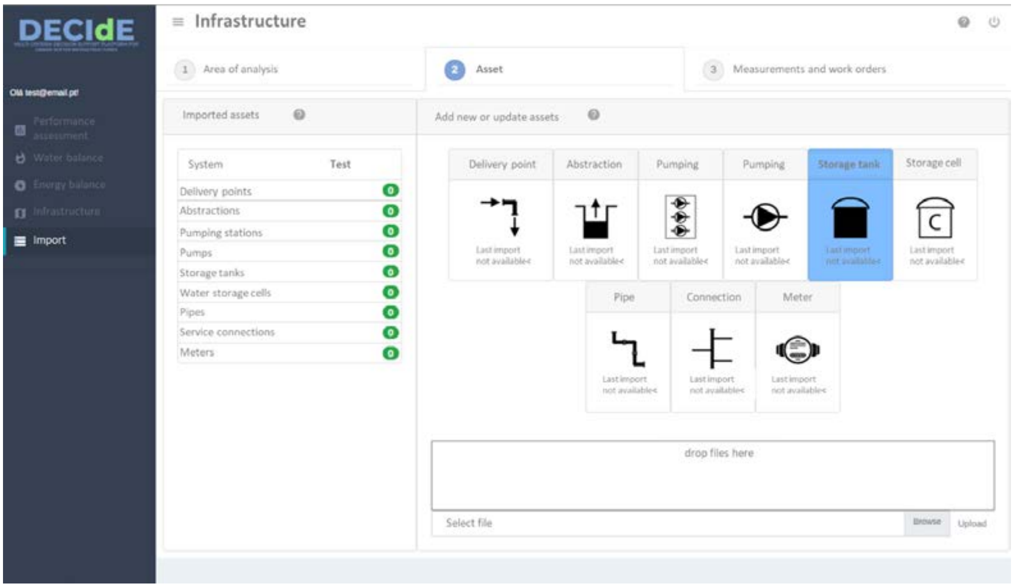

Figure 2. GUI of the data import module (Adapted from the Portuguese version).

 doi:10.20944/preprints202211.0295.v1

The platform is freely available on the web (https://decide.ips.pt/), though only a Portuguese version is implemented at this state; soon, a version in the English language will be developed. After a registration process, the user needs to upload their infrastructural data from their GIS and measurements files. The infrastructural data should be in the shapefile format since it is the most common format between GIS software.

3. Demonstration

The platform is illustrated herein for two water utilities with different maturity levels to highlight results that can be obtained with limited data and with a complete data set and to discuss the limitations of the analysis in each case.

3.1. *Water utility 1*

The first demonstration of the platform is with data from a municipality located in Lisbon's metropolitan area (Portugal), which manages a water distribution network with a total extension of 309.5 km serving about 79,000 inhabitants, divided into several subsystem and DMA. The utility has complete information about the existing assets stored in a GIS, motivated by several cadastral surveys, as well as a billing system and an information system to manage their service work orders.

Consider the utility wants to produce a tactical asset management plan for a specific DMA, and for that needs to carry out the diagnosis of the current situation. For that, the utility imports the physical asset data from its GIS using shapefiles, the monthly consumption from the billing system through spreadsheets and the available work orders also through spreadsheets. No aggregated water volumes nor energy consumption in assets (e.g., storage tanks, abstractions, pumping stations, delivery points) are included. As such, and with the available information uploaded, the utility can only calculate some of the performance indicators presented in Table 1, those shown in Figure 3. This example of bar representations shows the distribution of pipes in the analyzed DMA classified, using a three-colour scale, as good (green), average (yellow) or unsatisfactory (red) in each performance indicator.

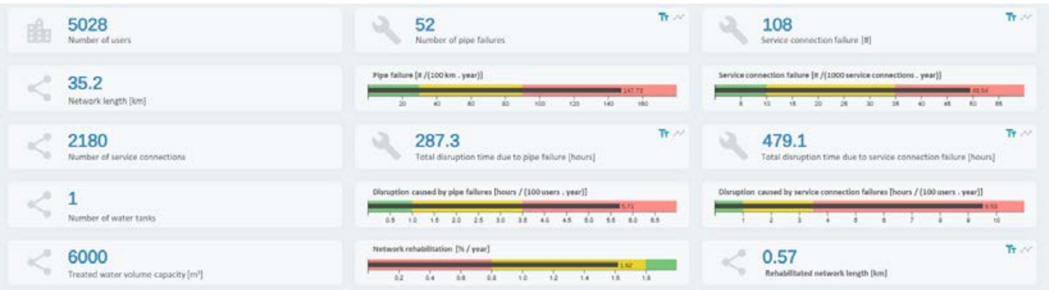

Figure 3. Summary of the performance indicators for water utility 1 (Adapted from the Portuguese version).

3.2. *Water utility 2*

The second demonstration of the platform is with data from a municipal company located in a touristic area, in the southernmost region of Portugal, which manages a water distribution network with a total extension of 85 km, serving a population varying between 3,000 inhabitants, in the low season, and 15,000 inhabitants, in the high season. This utility has complete information about its assets on a GIS which is regularly updated by a dedicated technician. It also has an information system to manage its work orders, and has its network completely monitored by several sensors (e.g., flow, pressure) connected to a SCADA system. Hydraulic simulation models of their complete network are also available. In comparison with water utility 1, this utility can calculate the same performance indicators (Figure 4), and also both the water balance (Figure 5) and the simplified energy balance (Figure 6), all classified using the three-colour scale according to the respective reference values of good, average and unsatisfactory performance.

Figure 4. Summary of the performance indicators for water utility 2 (Adapted from the Portuguese version).

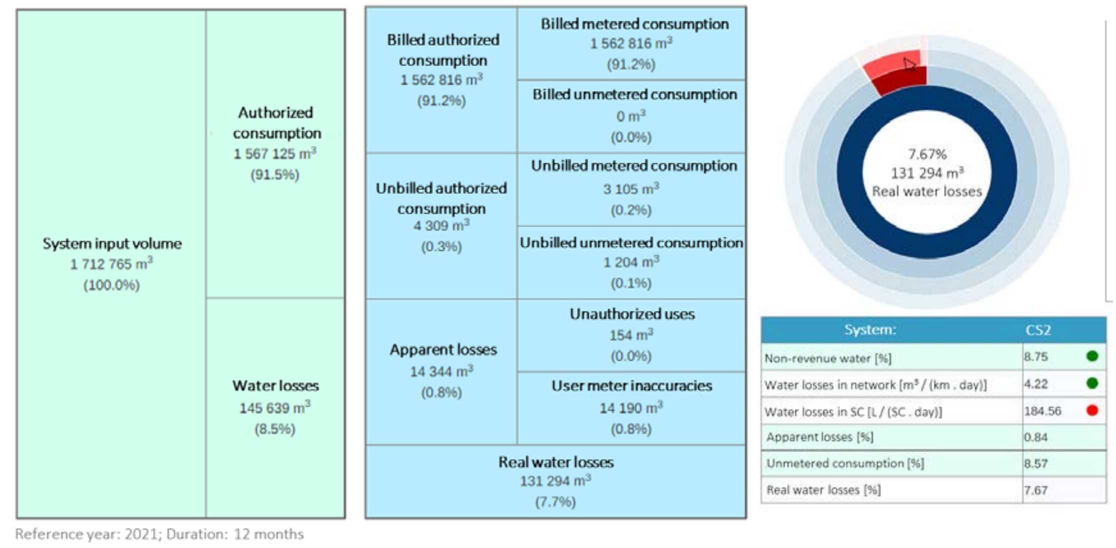

Figure 5. Water balance for water utility 2 (on the left) and the water losses performance indicators (on the right) (Adapted from the Portuguese version).

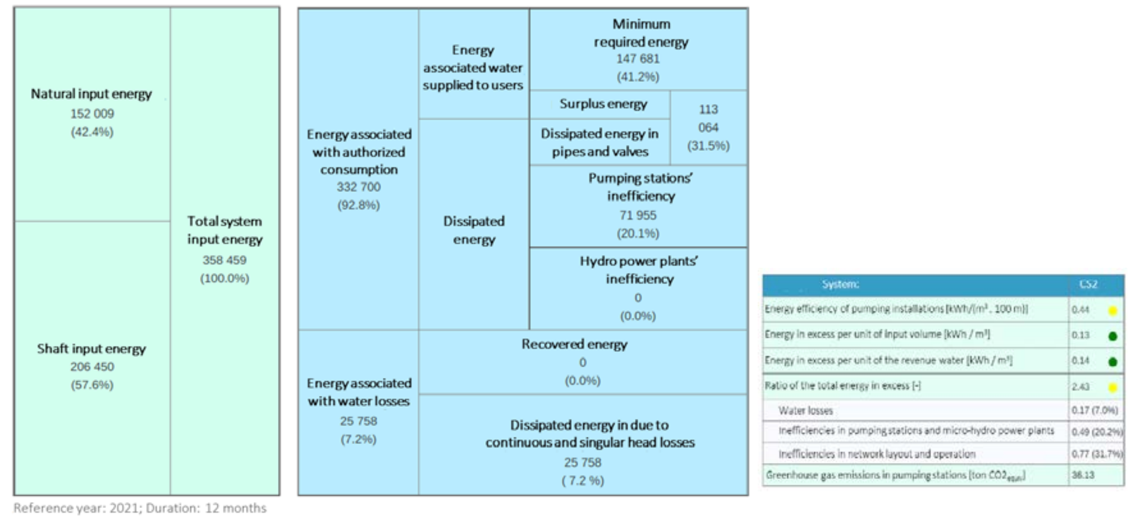

Figure 6. Energy balance for water utility 2 (on the left) and the energy efficiency performance indicators (on the right) (Adapted from the Portuguese version).

4. Discussion

The DECIdE project aimed at the development of a platform to support the IAM of water supply systems. An IAM methodology generally uses several techniques that are data-intensive and, for that reason, data integration or interoperability between existing IS is desirable. Nonetheless, data models are often unstructured in most utilities with a lower technological maturity level, containing inaccurate, incomplete, redundant, and out-of-date data, which ultimately turns data integration into a great challenge. Those data are stored in multiple and usually not compatible IS. However, the process of replacing an inadequate IS with a more suitable one is not always simple, as it may imply deep changes in the utility's information management processes. This fact may be aggravated in utilities with a lack of human and financial resources; the acquisition of a new IS implies a given amount of time dedicated for training, which in most cases they do not have. The above circumstances do not help the interoperability between IS in small and medium-size utilities.

The utilities with good financial capacity usually have the necessary resources to, internally or by subcontracting third parties, develop middleware applications for IAM. However, small to medium size utilities do not have the same financial capacity and often have difficulty in increasing their organizational and technological maturities. The national regulator can play an important role in data standardization by publishing recommendations in technical guides which can help the utilities with less maturity levels.

During the development of the platform, circumstantial choices about some technological aspects were made that now need further reflection. The use of MySQL technology for the database may not be the most adequate if in the future the platform is intended to be upgraded to receive real-time measurements from the sensors installed in the networks and to use them in artificial intelligence algorithms to perform advanced assessments. In this case, other types of database technology may be more feasible, such as document-oriented databases, graph databases, or even hybrid solutions.

Although the results of the performance indicators system are relevant to the water utility, the major advantage is the possibility is to assess the evolution of each indicator on a timely basis. This is of utmost importance to assess if the defined targets in the IAM plan are being achieved over time.

5. Final remarks

The platform presented herein represents a first step towards the development of a national reference tool to assist small and medium-sized water utilities to implement IAM processes. The platform will be further developed to include additional tools, namely: a flowrate and pressure time series data processing and analysis module, hydraulic simulation capabilities to carry more advanced performance assessment techniques, and IVI calculation. Additionally, the data model is expected to change to a different technology aiming to accommodate modules for more advanced techniques, such as pattern recognition, demand forecasting, and leak detection. The rationale behind the platform's development can be further extended to different fields in engineering where IAM is required, such as wastewater and stormwater, transportation, and oil and gas.

Author Contributions: Conceptualization, NC, BF, AA, D.C. and J.S.; methodology, N.C., B.F., A.A., C.G., R.B., A.M., D.C., L.M., J.S., and I.S.B.; software, A.A., and C.G.; validation, B.F, R.B., A.M., L.M. and I.S.B.; investigation, N.C., B.F., A.A., C.G., R.B., A.M., D.C., L.M., J.S., and I.S.B., data curation, N.C., B.F., and A.A..; writing—original draft preparation, N.C., and B.F..; writing—review and editing, A.A., and D.C.; supervision, N.C., R.B., A.M, C.G., D.C.. and J.S.; funding acquisition, N.C.. All authors have read and agreed to the published version of the manuscript.

Funding: This research was funded by Fundação para a Ciência e a Tecnologia, Programa Operacional Regional Lisboa 2020 and Programa Operacional Regional Alentejo 2020, grant number SAICT-POL/24135/2016 and | LISBOA-01-0145-FEDER-024135 | ALT20-03-0145-FEDER-024135. The APC was funded by Instituto Politécnico de Setúbal.

Data Availability Statement: The data presented in this study are available on request from the corresponding author. The data are not publicly available due to being obtained from third parties.

Acknowledgements: The authors acknowledge Fundação para a Ciência e a Tecnologia, Programa Operacional Regional Lisboa 2020 and Programa Operacional Regional Alentejo 2020 for funding this research and Instituto Politécnico de Setúbal for funding the APC. The authors also acknowledge the experts from the participating water utilities for their relevant and constructive contributions.

Conflicts of Interest: The authors declare no conflict of interest.

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