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A comparative analysis and implementation of indicators for sustainable water management

An application in Cascais

Tes Stuijt

Project Work presented as partial requirement for obtaining the master's degree in Information Management

NOVA Information Management School
Instituto Superior de Estatística e Gestão de Informação
Universidade Nova de Lisboa

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A COMPARATIVE ANALYSIS AND IMPLEMENTATION OF INDICATORS FOR SUSTAINABLE WATER MANAGEMENT

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by

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Project Work presented as the partial requirement for obtaining a Master's degree in Information Management, Specialization in Information Systems and Technologies Management

Advisor : Professor Miguel de Castro Simões Ferreira Neto

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DEDICATION

This project marks the end of my educational journey with Nova IMS. In the last 1,5 years, Nova IMS has abled me to gain knowledge on an area of studies that interests me most. Before I started my master's in information management, I had minimal experience with data. I searched for a master that could combine the theory of information gain with practical and usable skills. Nova IMS provided a big selection of electives to select from and even gave me the possibility to choose more electives than was mandatory to obtain my master's degree. With this option, Nova IMS stimulated my fellow students and me to educate themselves out of pure interest of a subject, not only to achieve the degree itself.

A sincere thanks to all those who contributed, directly and indirectly, to this master's degree. Also, to my advisor, Professor Miguel de Castro Neto, many thanks for providing a project that combines my sustainability and data interest. Next to that, thank you for your guidance, teachings, suggestions, and availability.

I dedicate this work to my parents, who always stimulated and supported me to educate myself, expand my boundaries and evolve.

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I would like to acknowledge Ana Cláudia Carvalho, who works in the department of innovation and communication at Cascais' Municipality. Thank you for your availability and time to help me. In October 2019, we passionately started to work out this idea to collect data and create these dashboards that were supposed to would be of real value for the Municipality of Cascais. In our eyes, the dashboards would give the Municipality additional insights into their water use patterns and empower them to make more precise decisions on a municipal level, thereby enforcing sustainable change. After months of creating a concrete plan with supporting literature, the Municipality announced that data needed to support this project was not available. However, as assured by the Municipality, the dashboards' concepts are considered a value for the future.

I would still like to thank Ana Cláudia Carvalho for her support over the last couple of months.

ABSTRACT

This research aims to identify and assess relevant indicators that follow a municipality's water management system's current state. Moreover, this paper will use the design research methodology to create a monitoring system's conceptual model that displays these identified indicators. Contemporary problems in water management are characterized by increasing complexity. Uncertainties due to climate change provide new challenges that humanity needs to tackle. Therefore, cities need to implement monitoring systems with clear indicators, clean data, set targets, and goals to successfully achieve their long-term sustainable development plans. The creation of a conceptual model is eventually to make this implementation more accessible to different municipalities. The defined indicators should meet the criteria to increase the usefulness and understanding for city managers and decision-makers from diverse backgrounds. Eventually, the goal is to apply this conceptual model to the Cascais water management case, where the local water indicators will be displayed in a Power BI report to see if Cascais' set climate action goals are on their way to being met.

KEYWORDS

Water indicator • Smart sustainable cities • Standardization Monitoring • Decision making • Sustainable Development Goals

INDEX

LIST OF FIGURES

LIST OF TABLES

LIST OF ABBREVIATIONS AND ACRONYMS

AdC	Agua de Cascais
AdP	Água de Portugal
AdTA	Water from Tejo Atlantico
BI	Business Intelligence
CMC	Municipality of Cascais
DSR	Design Science Research
DW	Data Warehouse
ETA	Water treatment plant
EPAL	Empresa Portuguesa das Águas Livres
ETAR	Wastewater Treatment Plant
ETL	Extract Transform Load
ETSI	European Telecommunications Standards Institute
INE	National Statistics Institute
IPMA	Portuguese Sea Institute and Atmosphere
IPCC	International Panel of Climate Change
IS	Information System
ISO	International Organisation for Standardization
ITU	International Telecommunication Union
KPI	Key Performance Indicator
OECD	Organisation for Economic Co-operation and Development
SMAS	Serviços Municipalizados de Água e Saneamento
SNIRH	National System of water resources information
UN	United Nations
WEF	World Economic Forum

"Climate change is moving faster than we are. We must listen to the Earth's best scientists."

- United Nations Secretary-General António Guterres

1. INTRODUCTION

Humankind has transformed the Earth for millennia. However, the consequences of these transformations have only become visible during the last decades (Steffen et al., 2015). Climate change is now contributing to severe changes in the Earth's system, including changing sea levels, ecosystems, species populations, and extreme weather events (IPCC, 2014). Consequently, climate change is one of the significant challenges for our century (IPCC, 2014).

One of the most pressing global risks will be the impact of the water crisis. The WEF concluded that the water crisis would have an extensive effect on environments, economies, and people (World Economic Forum, 2016). Climate change risks and water demand issues are already happening. In parallel, a different trend is occurring. Urbanization has colossal environmental consequences, both on a local and global level. More than half of the people on Earth live in cities, and the figure will only keep rising to more than two thirds by 2050, according to UN forecasts (United Nations, 2019). Cities are responsible for up to 70% of the world's greenhouse gas emissions (United Nations, 2019). The ever-increasing number of city residents puts incredible pressure on water and energy resources, waste management, sewer systems, and transport networks (United Nations, 2019).

Therefore, one crucial part of tackling climate change, avoiding lasting damage to vital ecosystems, and improving billions of people's health and well-being, we must seek solutions to these at the municipal level. The cities that understand and act upon this will be the ones that not only help save the planet from an impending crisis but will also be the first to attract investment and improve competitive position (World Economic Forum, 2016).

The recognition that climate change affects human security and global ecosystems leads to increased adaption research and implementation (Biesbroek et al., 2015). This increase in adaption research also applies on a municipal level. Adaptation to climate change on a local level is one of the new challenges municipal authorities will call for considerable efforts (Glaas et al., 2010). Therefore, when municipalities make plans for the upcoming decades, measures to cope with extreme weather events such as rising sea levels and intense precipitation are essential, namely, for securing municipal services such as (drinking) water, sanitation, energy, and education (Glaas et al., 2010).

1.1. BACKGROUND AND PROBLEM IDENTIFICATION

1.1.1. Municipality of Cascais

The Municipality of Cascais is one of these local governments that recognize the urgency of climate change and the need for adaptation on a local level. In 2015 a study was carried out by PECAC[1] for the Municipality of Cascais. This study concluded that, based on the global climate projections, three significant consequences of climate change would impact the local community: the increase in temperature, the difference in precipitation patterns, and an increasing extreme weather occurrence (IPCC, 2015).

"Climate change cannot be thought of as a problem for the future. Climate change is a problem of today, of every day. Its effects are already being felt in many ways and forms, with impacts on the economy and on the safety of the population."

- Carlos Carreiras, Mayor of the Municipality of Cascais

1.1.2. Cascais Action Plan

Anticipating the impact of climate change on the local community's daily lives has been one of the main concerns of the Municipality of Cascais. Therefore, to strengthen the community's resilience, develop opportunities for sustainable development, and stimulate local participation in environmental policies, the Municipality has created an action plan to adapt to the consequences of climate change. The Municipality of Cascais' mission is to implement its 13 defined goals to help the Municipality prepare for climate change's local impacts. These 13 defined goals comprise 80 actions and are to be achieved by 2030. Of these 13 goals, three goals are water management related. These three goals are in the table below. The corresponding actions are in Appendix A.

No.	Goal
1	The separation of wastewater and rainwater
2	The identification of alternatives to the provision of drinking water
3	The elimination of pollution in water lines

Table 1 - Cascais water measures

[1] http://cciam.fc.ul.pt/prj/pecac/

Firstly, the goal to separate wastewater from rainwater arises from the increasing amount of excessive rainfall that flows in the Cascais wastewater drainage systems. This increasing amount affects the sustainability of the services and the quality of life in urban environments (Cascais Ambiente, 2018). Considering the predicted increase in rainfall, enhanced by climate change, the increase in rainwater's undue inflow is considered a strategic issue. Secondly, the goal to identify alternatives for the provision of drinking water arises with the increasing average temperatures in mind. This goal can minimize the dependence on a single water supplier/origin for supply to the council of Cascais (Cascais Ambiente, 2018). Lastly, the goal of eliminating pollution water lines aims to contribute to the excellent quality of the creeks' waters and bathing waters. This area is one with much room for improvement, particularly with regards to compliance with environmental rules by users of the public water drainage network (Cascais Ambiente, 2018).

1.1.3. Cascais water matrix

To support these three actions and increase the probability of achieving them, the Municipality of Cascais conducted a research to map out information on the water management system, called the Cascais water matrix. The water matrix thus rose to identify, characterize, and quantify the main flows in the Municipality, together with the main actors in the water cycle in Cascais. The water matrix identifies several indicators divided into the sub-groups; supply chain, water consumption, drainage, wastewater treatment, and the Water Balance. The indicators identified in the water matrix are available in Appendix B.

1.1.4. Problem identification

A crucial tool for municipalities, such as the Municipality of Cascais that want to tackle the mentioned goals to improve the quality of life in their city, is the increasing amount of data they can use. Data enables cities to make correct decisions on the most appropriate policies and track changes and systematically document performance at the outcome level (Gil-Garcia et al., 2016). City managers require indicators for target setting, performance assessment, monitoring, and decision-making purposes. Cities require monitoring systems with clear indicators, clean data, set targets, and goals to successfully implement their long-term sustainable development plans. Such monitoring systems should track the progress made and identify obstacles with new techniques and approaches. The Municipality of Cascais is currently lacking a monitoring system like this that can help see how their water management is performing and if they are on the path of achieving their set goals. Therefore, this project's value will be to deliver a possibility of monitoring the water management performance of Cascais, with the end goal to support sustainable development through better decision making.

1.2. RESEARCH OBJECTIVES

This project's main objective is to propose a monitoring device to support city managers with decision-making considering water management. A conceptional model will be delivered containing a metric, dimensional model, and mock-up dashboards for local governments to get an insightful overview of water's current state within a municipality. Moreover, the case study aims to identify the most insightful indicators to support the decision-making process. This study will apply the proposed metric, dimensional model, and mock-up dashboard to the Cascais water indicator case.

- Create a *theoretical framework,* supported by the literature review that will focus on relevant areas of study, such as business intelligence and water management indicators.
- Create a *conceptual model* with the design and implementation of a business intelligence solution. This conceptual model contains the identification and creation of the electing the selection of the indicators to identify other relevant business intelligence defining the definition of formatting and visualization.
- Develop a *proof of concep*t that will contain the implementation and processing of the water data from the Municipality of Cascais and creating dashboards for the visualization of the selected indicators.

1.3. METHODOLOGY

The methodology that will be applied is design science research (DSR). The reason for selecting the DSR is that this method supports creating an artefact as a solution to a real-life problem. Considering this project, it will be the development of a water management monitoring system. This methodology, developed by Peffers et al. (2007), is a recommended method for creating successful artefacts. Its main objective is to structure and guide the production of artefacts and develop the knowledge of the area under study so that professionals can solve the proposed problems (Van Aken, 2005). The methodology's application is used frequently in the area of information systems (Vaishnavi & Kuechler, 2007), where its research often takes a more practical form (Peffers et al., 2007). The DSR methodology comprises six stages. Firstly, the problem definition defines the research problem and the value of the solution. Secondly, the purpose of objectives will support how the solution should look. Thirdly, the design and development comprise of the creation of the artefact and building the conceptual model. After that, the demonstration will prove if the conceptual model works on the case study. The evaluation stage observes how the artefact meets with the research objectives, and lastly, the communication stage evaluates the study's relevance. Ideally, the artefact provides a viable solution for the Municipality of Cascais to monitor its water management system.

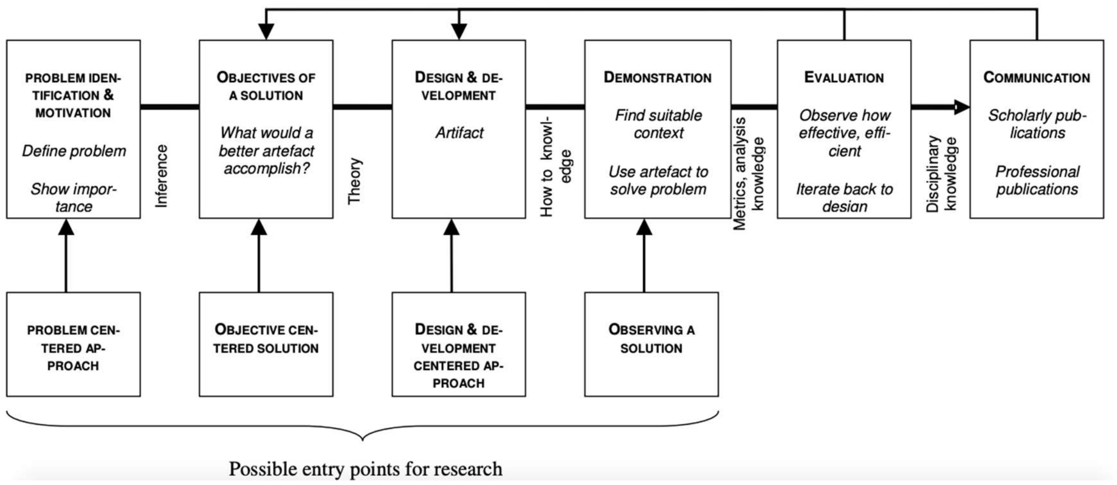


Figure 1 - Design Science Research. Adapted from Peffers et al., 2007

2. LITERATURE REVIEW

2.1. SMART SUSTAINABLE CITIES

Urban living already poses challenges in our daily lives. Urban cities are under increasing pressure due to enormous sustainability challenges, coupled with the most significant wave of urbanization in history (Kramers et al., 2014). More than half of the world's population lives in cities, and this figure will keep rising to more than two thirds by 2050, following the UN forecasts (United Nations, 2019). Cities are responsible for up to 70% of the world's greenhouse gas emissions due to the built environment's inefficiency, the intensity of social and economic related activities, and the density of the urban population (United Nations, 2019). Therefore, urgent solutions on viable living conditions and sustainable city development on a national and local scale are sought.

According to Bulkeley & Betsill (2005), the way for cities to move forward and cope better with the changing conditions is to adopt long-term approaches focused on technology and sustainability. On the other hand, the astounding development of information technologies and robust data analysis can offer solutions for sustainable city development (Bulkeley & Betsill, 2005). This development allows cities to become a smart, sustainable city. Essentially, the concept of "smart, sustainable city" combines urban sustainability and smartness, emphasizing that both aspects are considered simultaneously. The ITU defines smart, sustainable cities (2016a. p. 16) as "innovative cities that use information and communication technologies and other means to improve quality of life, the efficiency of urban operation and services, and competitiveness while ensuring that it meets the needs of present and future generations concerning economic, social, environmental as well as cultural aspects." One of the smart city methods is to monitor the improvement of set goals, in the form of identified indicators. In fact and according to Neto and Rego (2019), cities governments are nowadays under pressure and going through a digital transformation process to support higher efficiency resource usage that is leading to a paradigm shift where the city can be seen as a platform and urban planning and management is supported by urban analytics and real time data.

2.2. INDICATORS

Consequently, cities' necessity to become a smart, sustainable city is to define sets of urban indicators. Therefore, defined sets of indicators are being used to increase the probability that the goals and targets are being met, and monitoring this progress is feasible (Munier, 2011). Moreover, cities use indicators as a supporting tool when considering different decision alternatives. Another significant trend in the increasing use of indicators by city managers is increasing transparency towards citizens (Dameri, 2017).

As mentioned before, the increase in available urban data can provide a reasonable basis for successful city management (Gil-Garcia et al., 2016). However, it is not hard to get lost in all these urban data. Data is only valuable when it can be exploited (Jagadish et al., 2014). Thus, city indicators assist cities in identifying necessary data, setting targets, and monitoring their performance over time (ISO, 2018a). "Indicators are measures that can be tracked over some time to give insights on change concerning a particular phenomenon" (Kitchin et al., 2015). Moreover, indicators are generated and used as part of a suite of relevant measures that cross-validate trends and provide context (Godin, 2003). These trends are often discovered when charting them on graphs or maps.

City managers use indicators to set targets, assess city performance, monitor, and decision-making purposes. Thus, an important choice arises which indicators should be selected for systematic monitoring. This choice is essential while directly affecting the quality of decision-making in the city management (Kitchin et al., 2015).

2.2.1. Standardized Indicators

As stated before, city managers need indicators for measuring city performance. Commercial city indicators are often not standardized, consistent, or comparable over time or across cities (ISO 37120, 2018). Furthermore, commercial city indicators are criticized for their dubious motives, lack of scientific foundations, and transparency (Kitchin et al., 2015). As a solution, the standardization of indicators can harmonize indicators, reliability, and transparency in calculating and comparing results (Clarke, 2017).

International standardization bodies published multiple sets of smart and sustainable city indicators. Examples of these international standardization bodies are ETSI, ISO, and ITU. Standard indicators are useful, simplifying complex phenomena into understandable figures (Hiremath et al., 2013). These standardized sustainable city indicators are globally recognized, comparable, and consistent. Next to the available international standardization bodies, there are also widely accepted rankings that developed urban indicators and performed a comparison evaluation against cities based on these indicators.

2.2.2. Selection of indicators

"Indicators of sustainable development need to be developed to provide solid bases for decision-making at all levels and to contribute to a self-regulating sustainability of integrated environment and development systems." (United Nations, 1992) Many indicator frameworks and tools exist to assess urban sustainability and smartness (Albino et al., 2015). This abundance in indicator initiatives has grown to the extent that they are now considered part of an 'Indicator Industry' (Herzi & Hasan, 2004). With this abundance arises the question of how significant useful indicators are at operationalizing sustainability.

Moreover, this abundance in indicator standards makes it difficult for a city manager to make an informed choice on which indicator is most suited to monitor their set goals. It requires knowledge to understand the strengths and weaknesses of the indicator for a specific use. The abundance in indicator standards also makes it necessary for a city manager to compare these, considering the necessity to have reliable information while deciding which indicator standard to use. Therefore, with the vast amount of urban data and an abundance of indicator initiatives, a carefully selected and relatively small number of easily understandable KPI's is essential for municipalities to get an idea of the city's performance in several areas (Huovila, 2019).

Different factors are essential during the selection of relevant indicators. Firstly, to make a proper selection of indicators, it is favourable to divide cities into several *areas*. "The areas in which cities need indicators to measure the performance include energy, greenhouse gas emissions, transportation, digital infrastructure and services, resource management, citizens' participation, competitiveness, economy, environment, quality of life and research and knowledge creation." Kontinakis & De Cunto (2015) researched to understand what citizens view as priority necessities for a smart city. According to citizens, the priority necessities for a smart city were, amongst others, creating knowledge and innovation, developing public transportation, protecting the environment, improving education, and providing cleaner energy. The study by Kontinakis & De Cunto (2015) supports how certain relevant areas, such as water management, are. Secondly, it is essential to consider the indicator system's target group when selecting indicators for an evaluation framework. Decision-makers should consider these indicator system's target group.

Next to knowing the target audience, it is also essential to consider several vital distinctions between indicators. Firstly, the difference between single indicators and composite indicators. Single indicators consist of the measurement or a statistic related to a single phenomenon (Kitchin, 2014). On the other hand, composite indicators combine single measures using a system of weights with statistics to create a new derived measure (Maclaren, 1996).

Desirable single indicators are well defined and unambiguous, can be captured as a quantitative measure, and have strong representativeness (Kitchin, 2014).

Moreover, a single indicator is considered objective, value-free, independent of any influence, sensitive to change, traceable over time, verifiable and replicable, timely, easy to interpret, and cost-effective to collect, process, and update (Bhada & Hoornweg, 2009). Composite indicators, however, consider that different variables are interrelated and that a combination of indicators is more likely to reveal complexities underpinning an issue (Kitchin, 2014). Single indicators and composite indicators can be produced by municipalities or acquired from international standardization bodies such as ISO, ITU, and ETSI.

Moreover, during the selection process, a distinction between the typology of indicators should also be considered. The types of indicators are; input indicators, process indicators, output indicators, outcome indicators, and impact indicators. When evaluating a smart city project, there is an interest in which degree a city project contributes to reaching the set city targets regarding smart, sustainable development (Bosch et al., 2017). However, input, process, output, and outcome indicators also play a role in the smart city indicator framework. These indicators give an idea of the scale of effort which is needed to achieve impact.

Type of indicator	What is measured?	Type of assessment	When to use?
Input	Resources needed for interventions	Planning	Planning of needed resources to achieve some goal
Process	Implementation of activities	Quality assessment on means of implementation	Evaluation of implementation
Output	Effectiveness of implementation	Short-term monitoring	Reporting on immediate progress of implementation
Outcome	To which extent did the activities reach their objectives	Mid-term evaluation	Reporting on intermediate results (e.g adoption rate of urban solutions)
Impact	What was achieved by the interventions?	Long-term evaluation	Reporting on real impact or overall performance

Figure 2 - Types of indicators. Adapted from Bosch et al., 2017

2.2.3. City benchmarking

The process of city benchmarking consists of comparing urban indicators across or within cities to establish areas are performing compared to one another (Kaplan & Norton, 1992). The process makes it relatively accessible to discover which areas are doing well and have caught up or fallen behind (Kitchin et al., 2015). As a result, best practices can be found and implemented in different areas. Benchmarking, therefore, sets a competitive and aspirational agenda for municipalities when it comes to other local governances and thus is used as a motivation tool for necessary policy changes. To accomplish this city benchmarking process, you have to compare the same urban indicators on the different cities/city areas, monitoring them on a dashboard. It is facilitating a process of learning by monitoring and comparing (Huggins, 2003). Next to city benchmarking as a monitoring and comparing tool, selecting the same urban indicators helps to hold governments accountable for their actions.

2.3. BUSINESS INTELLIGENCE

Business Intelligence is defined as a system that collects, transforms and presents data in a structured matter, from various data sources (Negash, 2004). Business intelligence helps the management level of an organization to efficiently and effectively analyze the data in the organization. The overview of enterprise-related data helped the management to understand the current situation of their business (Karlsen et al., 2012). Moreover, Phan & Vogel (2010) defined BI as a process to enhance client information to improve the organization's processes next to the relationship with current and potential customers, with to goal to gain more profitability and competitive advantages. Turban et al., (2010) characterize BI as an umbrella term, which includes architectures, database, tools, applications and methodologies, to eventually al an access interactive and real-time data manipulation, where decision-makers and analysts can perform appropriate analysis.

Business Intelligence composes of several components. Firstly, the *data sources* are the basis for the developed solution. Secondly, the extract, transform and load (ETL) component has the sole purpose to standardize the data by correcting the errors, eliminating duplicates and unnecessary fields, calculate the metrics and, finally, reload the data into the Data Warehouse. The next component is the Data Warehouse, which has the function of a central repository of information from one or multiple data sources. Lastly, the component reporting entails the creation of dashboards and reports. The reporting component displays the most relevant information in a consolidated and organized way.

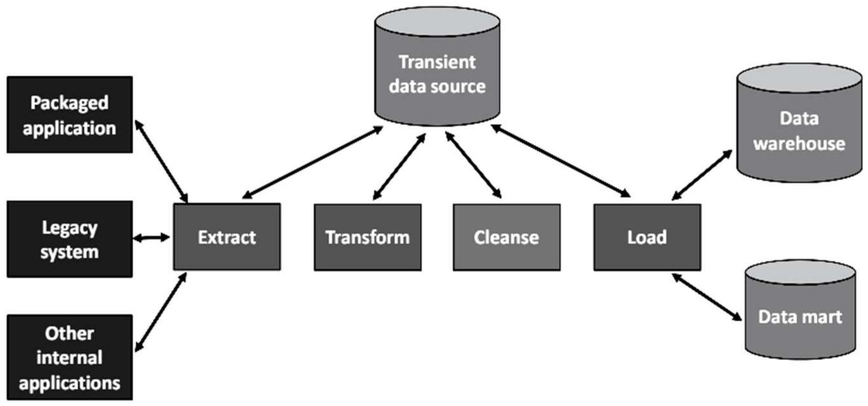


Figure 3 - ETL process. Adapted from Neto (2019)

2.3.1. Data visualization

With the help of a defined set of indicators, it became possible for organizations to quantify their targets and systematically monitor the progress towards their set goals (Munier, 2011). Additionally, it became possible for organizations to share data underpinning indicators with stakeholders though online, interactive data visualizations.

Over the past couple of decades, the use of indicators and data visualization has proliferated across public sector systems, including public services and public administration, to monitor and assess various aspects of a city such as sustainability, competitiveness, quality of life, well-being and urban services (Kitchin et al., 2015). On a municipal level, these data visualization initiatives help change the relationship between the Municipality and its citizens (Kitchin et al., 2015). Consequently, data visualization is ideally interpretable by the city managers as well as the citizens (Kitchin et al., 2015).

Data visualization as a tool has the power to make insights easier to understand and to act upon at every level in an organization. Unsurprisingly, dashboards have been a critical instrument for analysing and interpreting indicators. Data visualization transforms this data on indicators into information, resulting in insights by summarizing and communicating data through the use of statistical charts and graphs, diagrams, and maps (Wamba et al., 2013). Dashboards can represent data visualization.

2.3.2. Dashboards

The concept of a dashboard emerged because managers wanted better ways to communicate complex insights so they can quickly absorb the meaning of the data and take action (Wamba et al., 2013). Dashboards collect and display several indicators through a familiar graphic interface (Lake, 2013). For Few (2006, p. 34) a dashboard is "a visual display of the most important information needed to achieve one or more objectives; consolidated and arranged on a single screen so the information can be monitored at a glance". The exponential increase in the volume of data has triggered a need in organizations to create better decision-making processes based on rich sources of information, which has generated, by its turn, the increasing use of dashboards (Malik, 2005). Moreover, according to Eckerson (2005), institutions require dashboards that translate their strategy into goals, metrics, initiatives and tasks.

Firican (2017) developed some critical features for creating a powerful dashboard. According to him, a dashboard should be current and reliable, which entails that outdated data may lead to bad decisions. Therefore, showcasing the dates of the data is crucial. Moreover, titles, subtitles and descriptions of data should be made to inform the viewer what information they are inspecting. Lastly, the sentence "A picture is worth a thousand words" is considered while visualizations are proven to better support decision making.

3. THE CONCEPTUAL MODEL

The purpose of this chapter is to find out what kind of information should be presented on a dashboard. Next to that, it will dive deeper into the question which artefacts are necessary to make up a BI system. By answering these questions, it becomes possible to create a conceptual BI model that can be used by municipalities, like the Municipality of Cascais, for monitoring its water management.

Moreover, this chapter will cover steps such as creating an artefact, defining requirements, choosing indicators and selecting a software. The objective of the project is to create a business intelligence system to show the relevant water indicators, which will provide city managers with valid and timely information useful for monitoring and decision making. Ideally, the conceptual model can be used as a basis by different local governments for describing the characteristics and current state of their community. However, it is vital to keep in mind to adjust the conceptual model to a city's monitoring needs.

3.1. MODEL FOR MUNICIPALITIES WATER MANAGEMENT

3.1.1. Case profile and information requirements

The goal of the Municipality of Cascais is to get an insightful overview of their water management practices. Next to that, the Municipality wants to use this monitoring system to see if they can achieve their set climate action goals. Both city managers, as well as citizens, will have access to the dashboards. However, the primary purpose of the creation of the dashboards is to provide relevant information to support the city managers decision making and create a positive impact.

The monitoring system, in the form of a dashboard, will present multiple water-related indicators which divide into the categories water consumption and supply chain. See below a table with an overview of where the water-related information is divided categorically into different entities. Moreover, see also below the sources that theoretically provide this information.

Entities	Components	Source
Characterization of the Council Cascais	Resident population	*INE*
	Geography	*CMC*
	Water Resources	*SNIRH*
Water inflow	Water supply	*EPAL & SMAS*
	Precipitation	*IPMA*
	Domestic Consumption	*AdC*
	Wastewater from other Municipalities	*AdTA*
	Water Distributed	*INE*
Water outflow	Treated wastewater	*AdTA*
	Drained Wastewater	*AdC*
Water use	Consumption Municipality of Cascais	*CMC*
	Reuse of wastewater	*AdTA*

Table 2 - Overview entities, components and source (Cascais water matrix, 2019)

Supply chain data mostly comes from AdC. Águas de Cascais (AdC), the water supply management entity of Cascais monitors the systems functioning at all times. This all-time monitoring implies that there is enough data available on the entire Cascais water flow, the pressures and its water levels. The water supplied to the population of Cascais comes from Empresa Portuguesa das Águas Livers (EPAL) and after that is collected and treated in the Municipality by the management entity Águas de Cascais (AdC), together with the water purchased from the Sintra Municipal Water and Sanitation Services (SMAS). The subcategory water consumption gives an insight into the quantity an inhabitant consumes. This information originates from the water supply entity AdC. However, the Cascais Municipal Council (CMC) provides the data concerning the water consumption of the Municipality of Cascais.

3.1.2. General requirements

The general idea of creating a conceptual model is the possibility that other municipalities can effectively replicate the conceptual. A combination of internationally recognized indicators, as well as indicators preferred by the city managers, will be used. While local governments may have different goals set to achieve, the water indicators shown should provide the Municipality of Cascais specific with insights on their set goals as well as an overall understanding of the water management performance. The general requirements are:

▪ Provide an analysis of relevant water-related indicators yearly;

▪ To consolidate data by defined subcategory;

▪ Distribute the information to the city managers of Cascais.

3.2. INDICATORS

Given the objective of creating a BI artefact that needs to be applied to a distinct type of monitoring, local indicator preferences should be shown as well, as long as these indicator preferences are in line with the generally accepted indicators developed by the standardization institutions. This alignment is the only approach to guarantee that the final selection of indicators, which is visualized on the dashboards, is fair and consistent.

3.2.1. Benchmarking process

The Municipality of Cascais has conducted a research to map out information on the water management system, called the water matrix. In this document, several water-related indicators were identified. The list of indicators is divided into the sub-groups; supply chain, water consumption and drainage and wastewater treatment and can be found in appendix A.

However, as mentioned before, there are multiple institutions who created standardized indicators. Four of these international standardization bodies and two global sustainability rankings, which are widely accepted, were chosen as a source for the analysis.

- **ISO - International Organization for Standardization**

ISO is a worldwide federation of national standards bodies. "ISO develops high-quality International Standards that facilitate an international exchange of goods and services, support sustainable and equitable economic growth, promote innovation and protect the health, safety and the environment" (ISO 37120, 2014). ISO 37120 provides indicators to monitor sustainable development of communities, while ISO 37122 provides indicators to monitor smart cities.

- **ETSI - European Telecommunications Standards Institute**

ETSI provides key performance indicators for sustainable digital multiservice cities. ETSI aims to "speed up the transition to a low carbon, resource-efficient cities by facilitating and enabling stakeholders in smart cities to learn from each other, create trust in solutions, and monitor progress, using a common performance measurement framework" (ETSI, 2018). Now the goal is to support the deployment of smart city solutions on a broad scale, in order to impact the significant societal challenges related to the cities' fast growth and the energy and climate targets (ETSI, 2018).

- **ITU - International Telecommunication Union**

ITU aims to increase the use of information technology in smart, sustainable cities to assess the achievement of sustainable development goals (ITU, 2019). The indicators that ITU provides, therefore monitor this development of information technology in smart, sustainable cities.

- **OECD - Organisation for Economic Co-operation and Development**

OECD is an international organization that aims to build better policies for better living conditions. The goal is to shape policies that foster prosperity, equality, opportunity and well-being for all (OECD, 2019). The OECD works together with governments, policymakers and citizens to establish evidence-based global standards for solutions ranging from social and economic to environmental challenges. OECD uses their knowledge obtained from data analyses, exchange of experiences, best-practice sharing, advice on public policies and international standard-setting (OECD, 2019)

- **Arcadis Sustainable Cities Water Index**

The Arcadis sustainable cities water index is conducted to identify which city is harnessing its water assets to its most significant long-term advantage (Arcadis sustainable cities water index, 2018). The hope is that municipalities find these rankings useful to see water as an opportunity for economic development while simultaneously meeting the critical needs and safety of their residents and the environment (Arcadis sustainable cities water index, 2018). All of the included cities in the index have distinctive water relationships that help shape the urban character and define commercial identity and competitiveness. In order to analyze the management of water and whether it is sustainable, this report breaks down water sustainability into three core elements: resiliency, efficiency and quality.

- **Siemens Green City Index**

The Siemens green city index provides critical lessons from world cities on how to build a greener city (Siemens green city index, 2018). Similar to the Arcadis sustainable cities index, the Siemens green city index provides several indicators to help municipalities to understand their challenges better, as it provides them with insights into good policies and best practices. At the same time, it supports their decision making (Siemens green city index, 2018).

Table 3.2 provides an overview of the four international standardization bodies and two international sustainability rankings, and their number of water-related indicators. However, the benchmarking process can be examined in table 3.3. In this table, the most relevant water indicators are displayed, as well as which international standardization body and/or international sustainability ranking included the water indicator in their own selection of relevant indicators.

Institutions	ISO	ITU	OECD	ETSI	SDG	Arcadis	Siemens
Water Indicators	5	8	6	4	2	4	5

Table 3 - Water-related indicators per international standardization body

Indicators	ISO	ITU	ETSI	OECD	SDG	Arcadis	Siemens	Sum
Water Consumption	x	x	x	x			x	**5**
Grey and rainwater use	x		x					2
Water exploitation index			x					1
Water Loss	x	x	x				x	**4**
System leakages		x				x	x	3
Wastewater system treatment	x	x		x		x	x	**5**
Water efficiency and treatment policies					x		x	2
Water Charges						x		1
Reused wastewater	x			x	x	x		**4**
Grey and rainwater use				x				1
Freshwater abstraction for public supply per capita				x				1
Freshwater abstraction compared to available freshwater resources				x				1
Fresh Water Consumption		x						1

Table 4 - Benchmarking process International standardization bodies

3.3. Final Selection Process

After the benchmarking process, where the water indicators defined by international standardization bodies are compared, it is crucial to make a selection which of the indicators will be part of the final artefact. It is essential is to find a balance between the Municipality's preferences which water indicator should be monitored, the proposed indicators by the standardization bodies and the availability of the data. As we can see in the table above, some indicators repeatedly appear as recommended indicators by global standardization institutions. When making a selection which indicators should be considered as KPI's to be included in the dashboard, a threshold of four has been chosen, which can be found in the last column of table 3. This means that the following indicators will be considered on the water dashboard: water consumption, water loss and reused wastewater and wastewater system treatment.

Dashboard 1 - Water Consumption

Indicators
Water consumption
- Total water consumption
- Non-domestic water consumption
- Domestic water consumption
Water consumption by user
- Inhabitant
- Municipality
Water consumption by location
- Per parish within the Municipality

Table 5 - proposed KPI's water consumption

Dashboard 2 - Supply Chain

Indicators
Water that enters the Municipality
- % collected by different water facilitators
- purchased by the Municipality
- Non-Invoiced water
Treated wastewater reused
- Volume of water supplied
- Volume of wastewater produced
- Volume of wastewater consumed by the Municipality
Water loss
- Water loss detection
- Apparent and actual water loss

Table 6 - proposed KPI's supply chain

3.4. SYSTEM ARCHITECTURE

The architecture of the BI System can be divided into three main stages: data integration, data processing and data visualization. This whole process will be done in the Power BI tool.

1. Data Integration

As said in 3.1, there are multiple actors involved in the water management of Cascais, such as AdC, EPAL, SMAS and Guia's treatment plant. Many different actors increase the likelihood of data from different data sources. However, these data sources can be extracted from the operating systems and stored in the preparation area in Power BI. However, while historical data has been used for this case study, the only data source which is used is Excel.

2. Data processing

In this stage, the ETL process is carried out. ETL stands for extract, transform and load, and this is where the data is pre-processed or cleaned. After cleaning the data, it will be transformed into representable data and subsequently loaded into the Data Warehouse.

3. Data visualization

After the ETL process, the data is to be effectively presented through the data visualization tools that power offers. The BI System must grant in a fast, automated and flexible way, all the information necessary for decision making.

3.5. Dashboard design

Wong (2017) stated that there are three essential elements to creating good information graphics; rich content, inviting visualization and sophisticated execution. Firstly, rich content brings meaning to a graphic. Secondly, inviting visualization interprets the content and highlights the essence of the information for the reader. Lastly, sophisticated execution brings the content and the graphics to life. Remember, a picture is worth a thousand words. With this in mind, the following artefacts will be described on the dashboard:

- Dashboard name as well as the name of the Municipality, must be identified.
- *Formatting Rules:* the colours on the dashboard should be influenced by the subject related colours. The selection of the colours into charts should be made gracefully (Wong, 2017). They are choosing harmonious combinations, such as different shades of the same colour. Next to that, do not choose the colours arbitrarily. Choose them strategically to compare and contrast data effectively (Wong, 2017).
- *Views:* The construction of the panels should be customized in order to be useful for every type of institutions or subject (Malik, 2005). In the case of the Water indicator dashboard, the dashboards will be focusing on a specific subject.
- *Filters:* All dashboards must have filters that give the city managers as well as the citizens of Cascais the option to specify specific periods or areas. While this dashboard will be created for both the city managers as well as the citizens, this latter option is especially while different audiences are involved. Moreover, these different audiences need more detailed information about different areas of interest.

Component	Format
Dashboard titles	Font Arial Black; size 40; Colour black #000000
View titles	Font Arial; size 14; colour black #000000
Foreground	#FFFFFF
Background	#AEBBCB Transparency 80%
Data colours	#003366 #A8C5E0 #214F80 #A4D3E3 #82A1BD #366996
Tiles background	#000000
Titles Front color Title background-color	 #FFFFFF #003366

Table 7 - Dashboard format

4. PROOF OF CONCEPT

This chapter contains the implementation of the conceptual model. In the previous chapter, the essential components of the dashboard were established. In this chapter, the Cascais water management case study will be connected to this defined dashboard. The indicators found in the previous chapter, together with the measurements, will be connected to the case study. Later on, technical procedures are developed concerning the integration and processing of data, ranging from the creation of relations between the various bases of data to the design of metrics to obtain the calculations of specific indicators. Finally, there will be the design and conception of dashboards, being this an "invisible" phase in the report, but the result will be presented.

4.1. DATA SOURCE CHARACTERIZATION

Initially, the necessary water data would be delivered by the Municipality of Cascais in the form of an excel file. The argumentation for this was because it would help structure the data which comes from multiple actors. Unfortunately, the Municipality of Cascais was not able to collect and structure this data. As a solution, the utilized dataset for the metrics and dashboards is self-collected in an excel file retrieved from the Cascais water matrix. The dataset highlights the water data between 2013 and 2017.

4.2. PERFORMANCE INDICATORS TO BE IMPLEMENTED

As mentioned before, the indicators that will be displayed on the dashboard combine indicators selected by the city managers of Cascais, the indicators defined by international standardization bodies and the indicators that we are able to be collected with the available data. The selected indicators will be listed and grouped in the following paragraph of the report. To make the dashboards understandable as possible, they are grouped as follows: water consumption and supply chain.

4.2.1. Water Consumption

No. 1	**Average water consumption per inhabitant by parish**
Description	Total water consumption per inhabitant of a parish gives an indication of water used by the population as well as an indicates the access to water. The data focuses on the following four parishes; 1) Alcabideche, 2) Carcavelos and Parede, 3) Cascais and Estoril, and 4) Sao Domingos de Rana.
Calculation	**Numerator:** Total water consumption per parish **Denominator**: Total population per parish
Indicator Unit	litres/capita/year
Data source	Cascais water matrix
Insightful	The increase or decrease in water consumption per inhabitant relative to the previous years
References	ETSI, ISO, ITU, OECD, Siemens Green City Index

No. 2	**Evolution of total water consumption by parish by year**
Description	Indicates the total water consumption per by year in proportion to the parishes in the Municipality of Cascais. The data focuses on the following four parishes; 1) Alcabideche, 2) Carcavelos and Parede, 3) Cascais and Estoril, and 4) Sao Domingos de Rana.
Calculation	Amount of water used per parish
Indicator Unit	litres/capita/year
Data source	Cascais water matrix
Insightful	Insightful for the Municipality to understand which parish is a considerable water user and with that this indicator gives an understanding of its trend and proportionality.
References	ETSI, ISO, ITU, OECD, Siemens Green City Index, Cascais water matrix

No. 3	**Total non-domestic water consumption by parish by year**
Description	An overview of water used in a non-domestic context. refers to the consumption in other buildings than houses, namely in commercial establishments, offices, hotels, hospitals, schools and factories, among others (Cascais water matrix, 2019). This indicator considers the following four parishes; 1) Alcabideche, 2) Carcavelos and Parede, 3) Cascais and Estoril, and 4) Sao Domingos de Rana.
Calculation	Amount of water used in a non-domestic context by parish
Indicator Unit	litres/capita/year
Data source	ERSAR (2013)
Insightful	Insightful for the Municipality to understand their water usage patterns and provides city managers with the possibility to reduce their water use.
References	Cascais water matrix

No. 4	**Total water consumption by the Municipality of Cascais**
Description	The volume of water consumed by the Municipality of Cascais, who are responsible for about 25% of the non-domestic water consumption. The water uses of the Municipality are also diverse, given the variety of services and activities that the municipality manages.
Calculation	Total amount water consumed by the Municipality
Indicator Unit	litres/capita/year
Data source	ERSAR (2013)
Insightful	Insightful for the Municipality as well as its citizens to understand their water usage patterns of the Municipality of Cascais, and to consequently help reducing water usage.
References	Cascais water matrix

No. 5	**Volumes of treated wastewater consumed by the Municipality**
Description	The volume of treated wastewater consumed by Cascais Ambiente. This treated wastewater is used for cleaning the streets, squares and the tunnels to the beaches (Cascais water matrix, 2019).
Calculation	Amount of reused water consumed by the Municipality
Indicator unit	million m3/year
Data source	Cascais water matrix
Insightful	This indicator makes it possible to compare the current volume of treated wastewater to the target volume
References	ISO, OECD, SDG, Arcadis

No. 5	**Proportion of domestic water consumption per parish**
Description	The percentage of total domestic water consumption in proportion to the other parishes in the Municipality of Cascais. The data is divided into four parishes, namely; 1) Alcabideche, 2) Carcavelos and Parede, 3) Cascais and Estoril, and 4) Sao Domingos de Rana.
Calculation	**Numerator**: Amount of total water consumption by parish in one year **Denominator**: Total domestic water consumption of all parishes in one year
Indicator Unit	Percentage of total
Data source	Cascais water matrix
Insightful	Compare the trends in water consumption relative to the four parishes in one year.
References	Cascais water matrix

4.2.2. Supply Chain

No. 1	**Percentage of water entering Cascais through the authorized supply system**
Description	Every year, between 17.6 and 19.0 million m3 enter Cascais of water for human consumption through the supply system of Águas de Cascais. There are 3 main suppliers that play a part in the water supply of Cascais, namely EPAL, SMAS Sintra and the Municipality of Cascais.
Calculation	**Numerator**: authorized water supply EPAL **Denominator**: total water entering the system **Numerator**: authorized water supply Municipality of Cascais **Denominator**: total water entering the system **Numerator**: authorized water supply SMAS Sintra **Denominator**: total water entering the system Multiplied by 100
Indicator Unit	Percentage of total
Data source	Cascais water matrix
Insightful	These percentages provide an understanding of the distributions of the main water supply into the Municipality.
References	ISO, ITU, ETSI, Siemens green city index

No. 2	**The proportion of the main components of the water balance supply system**
Description	The total amount of water that enters the Municipality divided in the proportions of authorized water supply, apparent water losses and actual water losses. The sum of illicit uses and losses of water due to measurement errors constitutes the apparent losses of the municipality (Cascais Water Matrix, 2019).
Calculation	**Numerator**: authorized water supply **Denominator**: total water entering the system **Numerator**: actual water losses **Denominator**: total water entering the system **Numerator**: apparent water losses **Denominator**: total water entering the system Multiplied by 100
Indicator Unit	Percentage of total
Data source	Cascais water matrix
Insightful	These ratios provide an understanding of the distributions of the main components. Thereafter, it can be used as a starting point on how and where water losses occur.
References	ISO, ITU, ETSI, Siemens green city index

No. 3	**Volumes of water supply and volumes of wastewater produced**
Description	This indicator shows the annual wastewater production between the years 2013 until 2017 against the volume of water wastewater sent for treatment
Calculation	▪ The volume of wastewater supplied ▪ The volume of wastewater treated
Indicator Unit	type/million m3/year
Data source	Cascais Water Matrix
Insightful	Get insights into the variation in wastewater volume send for treatment and if this amount is similar to the trend in volumes of water entering the drinking water supply system.
References	ISO, ITU, OECD, Arcadis, Siemens Green City index

No. 4	Wastewater treated for reuse
Description	Guia's treatment plant can treat 9000 m3/day of wastewater with quality suitable for reuse in various purposes (Cascais water matrix, 2019). This indicator shows the total amount of water that is produced for reuse against the amounts of reused water that is consumed by Cascais Ambiente and Guia's treatment plant.
Calculation	▪ The volume of total water produced for the volume of reused water consumed by Cascais Ambiente ▪ The volume of water reused consumed by Guia's treatment plant
Indicator Unit	million m3/year
Data source	Cascais Water Matrix
Insightful	Insightful to monitor the increase or decrease of reused water by Cascais Ambiente Guia's treatment plant in proportion to the total amount produced for reuse.
References	ISO, OECD, SDG, Arcadis

No. 5	Evolution of actual and apparent losses
Description	A part of the water inflow does not reach the taps of Cascais' citizens. There are several reasons for water losses. Water can get lost due to leakages in the pipes, in the reservoir overflows (real losses), or it can be removed illegally from the system (unauthorized use). However, water losses can also occur due to errors associated with measurement equipment, processing and data treatment systems. The sum of illicit uses and water losses due to measurement errors constitute the apparent losses of the Municipality (Cascais water matrix, 2019).
Calculation	▪ **Apparent losses** = The sum of illicit uses and water losses due to measurement errors ▪ **Actual losses** = The sum of water inflow that does not reach the Municipality
Indicator Unit	million m3/year
Data source	Cascais Water Matrix
Insightful	Understanding the urgency of decreasing water losses.
References	ISO, OECD, SDG, Arcadis

No. 6	**Evolution of actual loss per supplier**
Description	The sum of water inflow that does not reach the Municipality per supplier per year (Cascais water matrix, 2019).
Calculation	▪ **Actual losses** = The sum of water inflow that does not reach the Municipality
Indicator Unit	million m3/year
Data source	Cascais Water Matrix
Insightful	Being able to compare the performance per supplier on actual water loss.
References	ISO, OECD, SDG, Arcadis

4.3. SOFTWARE CHOICE

For the implementation of the project, the Microsoft Power BI program is the software. Power BI is a business analytics solution from Microsoft that visualizes and shares data through (live) dashboards and reports. Microsoft Power BI can turn unrelated sources of data into coherent, visually immersive and interactive insights. An advantage of Power BI is that the input data can be delivered in multiple forms differing from an excel spreadsheet to a collection of cloud-based hybrid data warehouses. Power BI provides a strong connection with diverse data sources, whereby visualization and discovery can be found and shared. Microsoft Power BI can satisfy the city managers as well as the citizens of Cascais as its end-users. Next to that, Power BI will be carrying out the ETL process, while it is able to connect to several data sources, such as XML, CSV, Excel, and many more. Power BI is able to create an integrated environment with data from various sources. It also serves as a repository for data extracted.

4.4. DATA INTEGRATION AND PROCESSING

The first step in the experimental phase is the construction of the artefact is the ETL process. Here the described data is uploaded into the Power BI system and 'cleaned' so that it is consistent. Training standards are applied here, as well as the removal of errors and unnecessary data, the renaming of data categories so that they can facilitate the relationship between different tables. While the data used for this project has already been selected based on its relevance and is created hands-on, the process in this project report is reduced to checking if the relationships defined in the data model are correct or need rearrangement.

4.5. DIMENSIONAL DATA MODEL

The next step contains defining the attributes that are common and creating relationships between these attributes. Moreover, fact tables and dimension tables will be created. Fact tables contain all primary keys of the dimension and associated facts. Dimension tables on the other had provided descriptive information for all the measurements recorded in the fact table. Eventually, the goal is to simplify a complex normalized set of tables and consolidate data into one database structure that can efficiently be queried.

Firstly, the fact tables are listed and described.

- **FactWaterbalance** shows the information on the inflow and outflow of water to the Municipality of Cascais. Moreover, FactWaterbalance shows information on the water input from the three leading water suppliers; EPAL, the Municipality of Cascais and SMAS Sintra. The table contains water data from the years 2013 to 2017.

- **FactWastewater** gathered information on wastewater inflow and outflow concerning the Municipality of Cascais. It provides information on wastewater produced as well as wastewater consumed and reused.

- **FactConsumption** distinguishes total, domestic and non-domestic consumption. Subcategories are there to make a relative comparison between the water consumption in the 4 different parishes.

Secondly, the dimension tables are listed and described. The creation of the dimension tables is necessary while they contain unique attributes for each type of data.

- **DimTime** provides the dimension of time containing the years between 2013 to 2017.

- **DimSupplier** provides us with information on the three biggest suppliers within the water supply, namely: EPAL, Municipality of Cascais and SMAS Sintra.

- **DimParish** gives information on the parishes, the cities within a parish, its surface and the Municipality. This data is by the NUTSI standard.

Fact Table	Dimension Table	Common Attribute
FactWaterbalance	DimTime	Year
	DimSupplier	Supplier
FactConsumption	DimParish	Parish
	DimTime	Year
FactWastewater	DimTime	Year

Table 8 - Overview fact tables and dimension tables

4.6. METRICS

Figure 4.1 represents the data model, containing the tables with numerous attributes. The relationships between the fact tables and dimension tables are visible in the data model. There are three types of relationships visible in the data model, a one-to-one, one-to-many and many-to-many relationship. In a one-to-one relationship, one record is associated with one record in another table. In a one-to-many relationship, one record in a table associated with multiple records in other tables. Lastly, many-to-many can have multiple records in one table associated with multiple records in another table. However, in this dimensional model only the one-to-many relationship occurs.

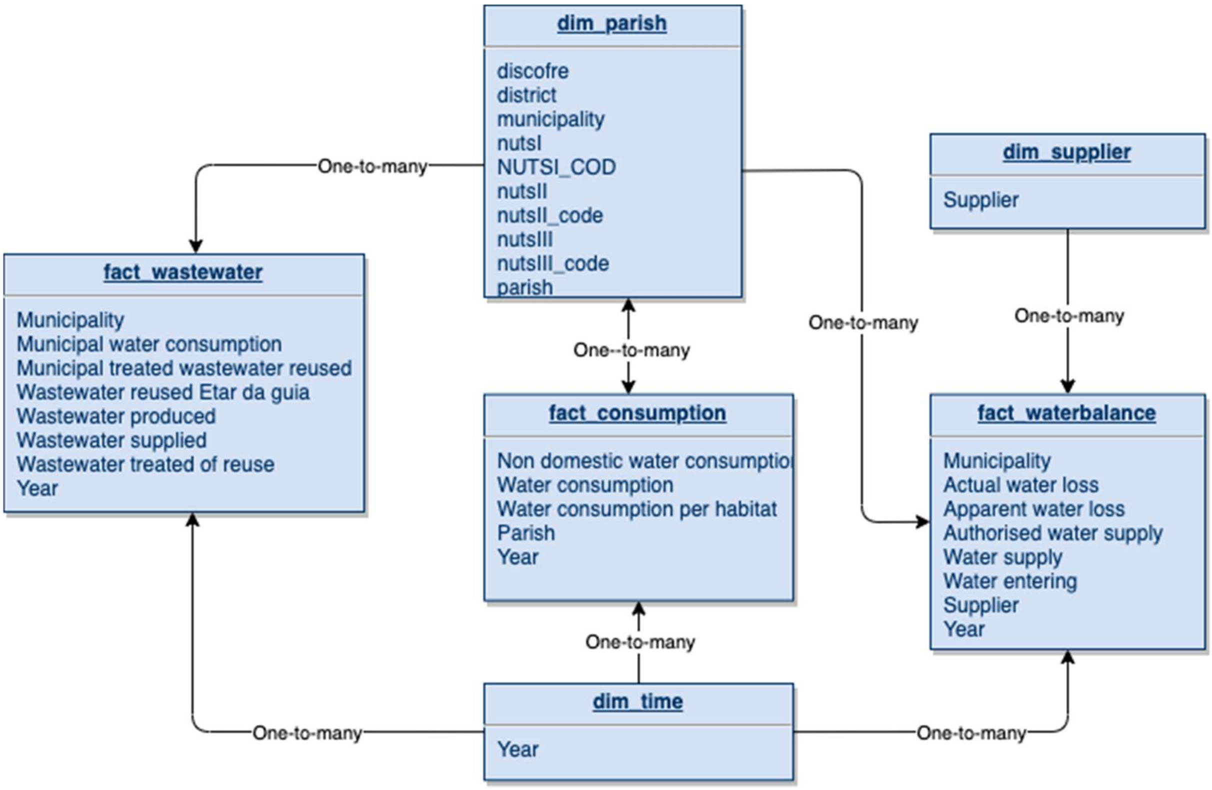
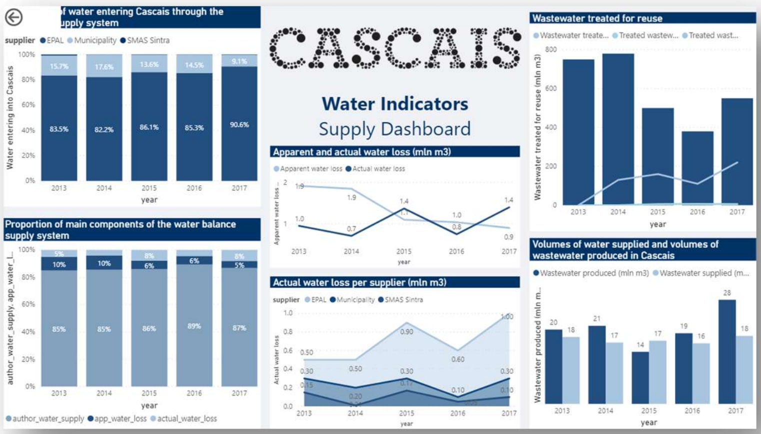


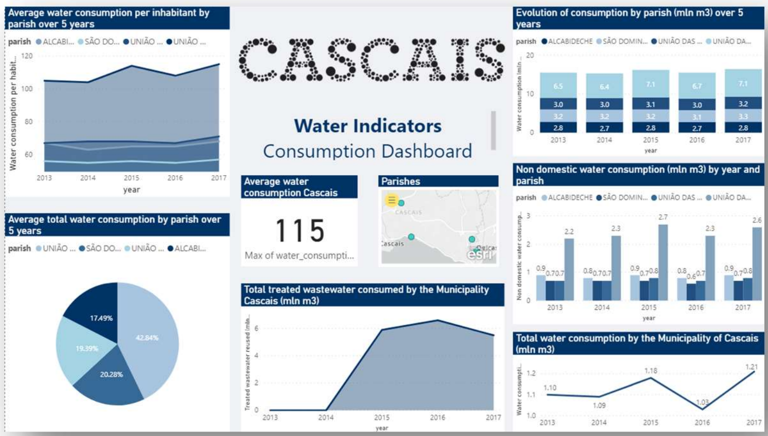
Figure 4.1 - Dimensional Model

4.7. DASHBOARDS

The final phase of the proof of concept materializes in the design and conception of the dashboards.

The design process of the dashboards is impossible to describe in the report. However, it is essential to know that the dashboards are created, taking into account the directives defined in Chapter 3, Chapter 4 and are a result from the application of all knowledge acquired during the work. The final result is represented in the figures below.





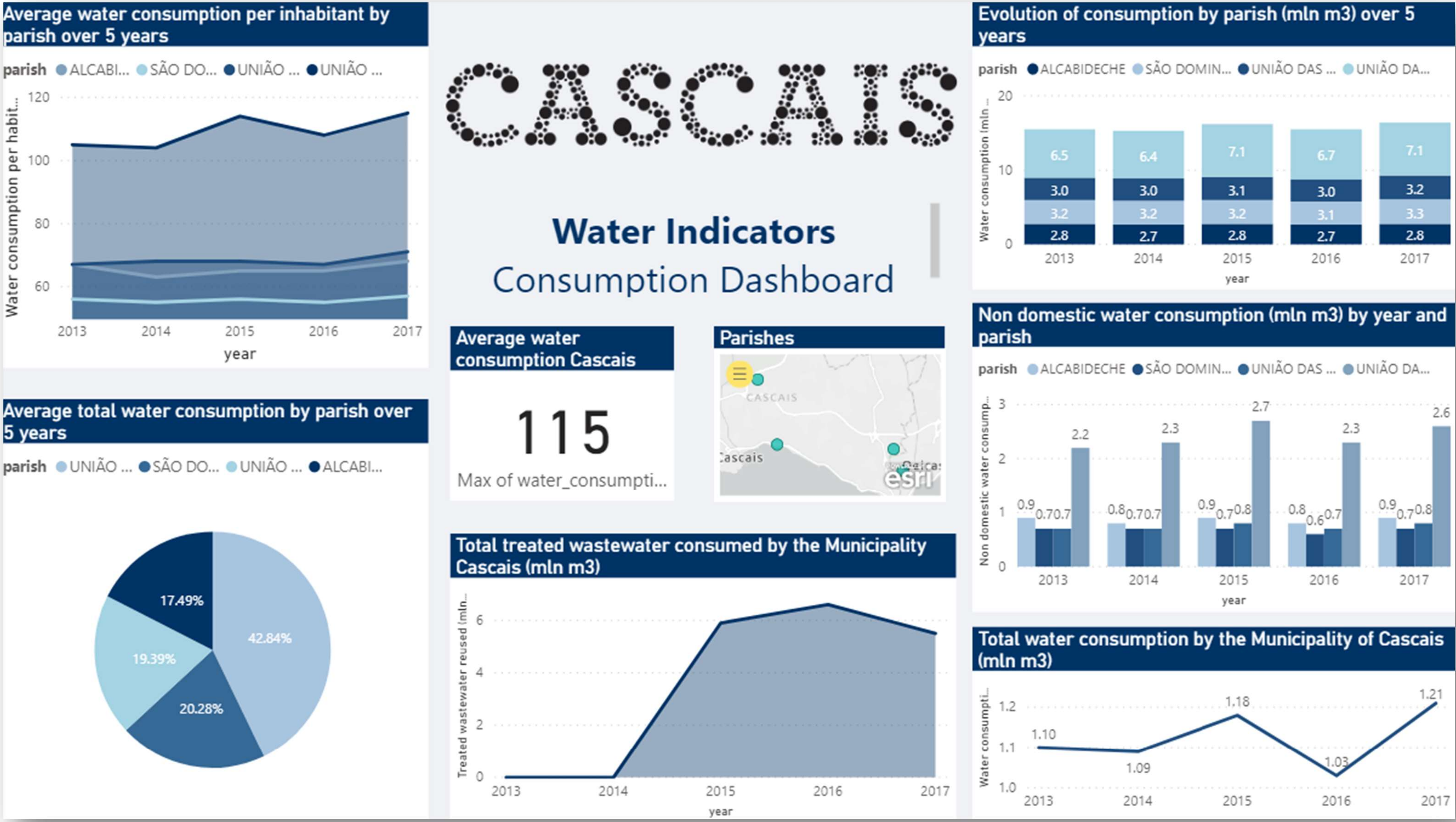


Figure 4.3 - Consumption Dashboard

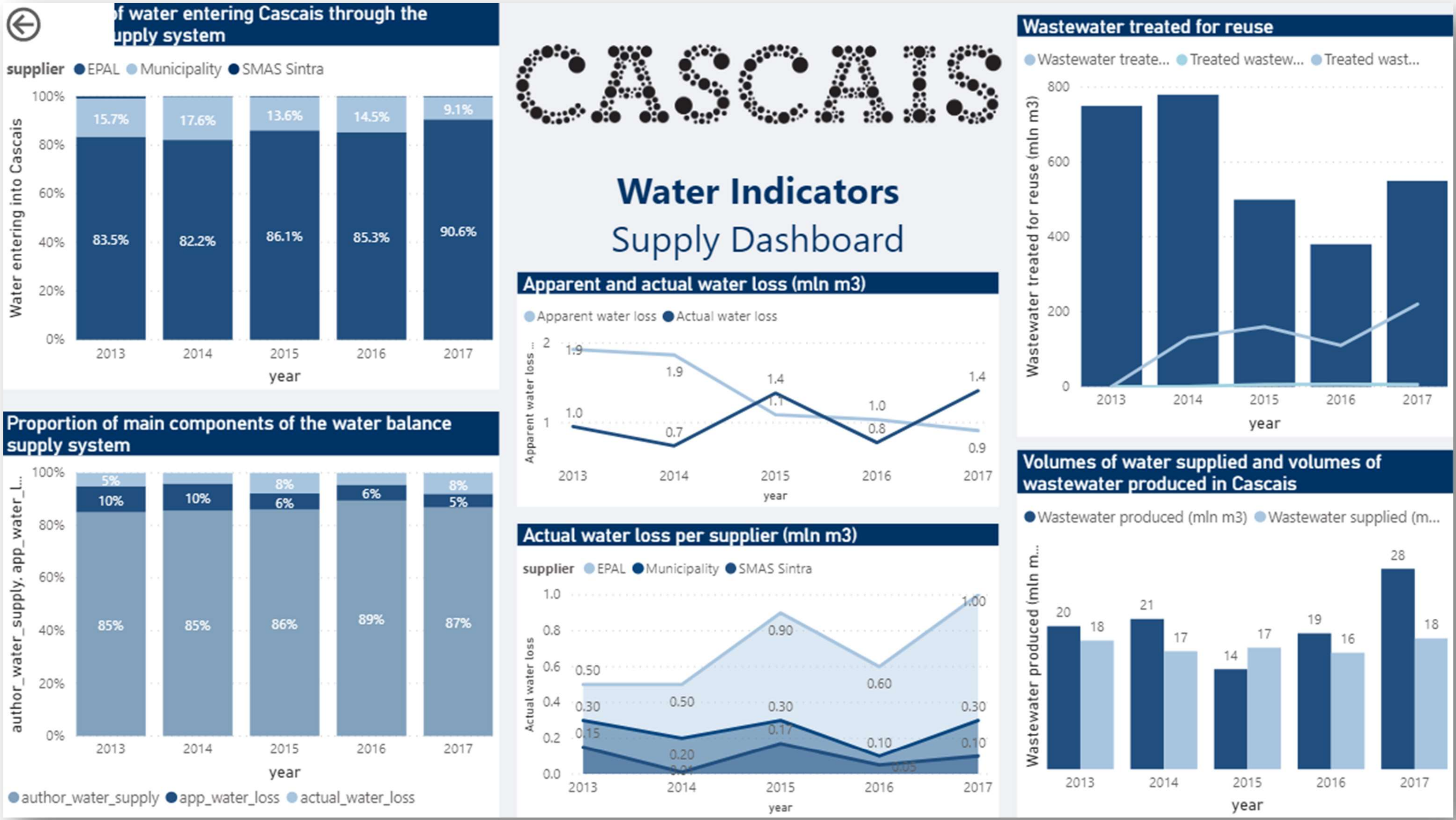


Figure 4.4 - Supply Dashboard

5.1 Dashboard Water Consumption

The indicators related to water consumption make up the first part of the results. Once the data is collected, it allows visualizing of various types and perspectives of water consumption in various parishes over different years. When looking at the first graphic representation, *Average water consumption per inhabitant per parish (and in total) per year,* it becomes clear that there is a specific trend in water use. This line chart provides information on the evolvement of water consumption per inhabitant through five years, relatively to one another. Although water consumption over the last five years has been relatively constant, this view has a practical value to notice trends over an extended period.

The average yearly water consumption per inhabitant has remained relatively constant between the years 2013 and 2017 per parish. However, what does stand out is the clear difference in consumption between the three parishes Alcabideche, Carcavelos and Parede and Sao Domingos de Rana, and parish Cascais and Estoril. This clear difference can also be seen in the graphic representation *Average total water consumption by parish*. This pie chart compares the percentage of yearly water consumption of the four parishes. The capitation in Cascais and Estoril is, with its 42,84% of the total water consumption, by far the biggest piece. This difference is especially visible when comparing Cascais and Estoril to the other parishes. However, the high consumption of water in the parish of Cascais and Estoril is explainable by the greater use of the system water for outdoor uses, such as the filling of pools and the watering of gardens, result of the prevalence of single-family homes (Cascais water matrix, 2019). Also, non-domestic water consumption, which contributes to 30% of the total water consumption in Cascais, plays a role in the big differences between de parishes. Non-domestic water consumption refers to the consumption in buildings other than inhabitant houses. Think about buildings such as commercial establishments, hotels, offices, hospitals, schools and factories. The captions of non-domestic consumption, as well as water uses, are variable depending on the type of activity and the size of each consumer. For example, in schools, most of the consumption of water occurs in toilets, while in the restaurants the most prominent use is in the kitchen. A significant fact to mention is that the Municipality of Cascais is responsible for about 25% of the non-domestic consumption (Cascais water matrix, 2019). The water use of non-domestic water in the Municipality of Cascais is clearly visibly in the bar chart *Non-domestic water consumption per parish.* With a consumption of more than three times as much than the three other parishes, Cascais and Estoril have the highest non-domestic water consumption. Unlike domestic consumption, non-domestic consumption has shown small fluctuations between 2013 and 2017. The years with higher consumption were in 2015 and 2017, matching the years of severe drought. However, this small increase is only noticeable when looking at the data of parish Cascais and Estoril.

In the line chart *Total water consumption by the municipality of Cascais* we see the same fluctuations in water consumption as the mentioned before. For municipal consumption, this increase can be explained with the knowledge that the watering of green spaces was identified as the main water use, representing about 67% of consumption. So, when the drought is above average drought, more water is needed to maintain the municipal green spaces. Of the 1319 Installed meters, 914 measure water consumption due to watering diverse green spaces, such as gardens, parks and traffic circles (Cascais Water Matrix, 2019). Apart from that, the water uses of the Municipality are diverse, given the variety of services and activities that the municipality manages.

Following the *Volumes of treated wastewater consumed by Cascais,* the primary use of this water has been as service water which does not require a high level of quality for human consumption. As can be seen in the line graph in the bottom right corner, in 2015 Cascais Ambiente started with the use of treated wastewater for street washing of the Municipality. The volumes of treated wastewater consumed by Cascais Ambiente are between 5500 to 6600 m3/year, the which corresponds to less than 2% of the total wastewater treated at Guia's treatment plant.

The bar chart *Volumes of treated wastewater consumed by Cascais Ambiente* shows tot total use of treated wastewater by the Municipality. Cascais uses the treated wastewater for the cleaning of streets, squares and the tunnels to the beaches. There is much potential to increase consumption of this water for other uses. Visible in the bar chart, about half of the wastewater treated is not yet used for any purpose. Potential uses of treated wastewater include the watering of golf courses and green spaces, car wash and the washing of urban space. The national target of 2030 is to utilize 20% of the wastewater treated.

4.8. Dashboard Water Supply

The second dashboard shows water supply related indicators. This dashboard can be found in figure 4.4 and presents various information, including water inflow, water outflow, wastewater, reused wastewater, amongst others. In the bar chart *Water entering Cascais through authorized supply system,* it can be seen that the most significant amount of the water entering Cascais comes from the EPAL adductor system, which is between 82% to 91% for the period 2013-2017. The second largest supplier, the Municipality of Cascais, contributed to approximately 15% of the total water entering Cascais in the years 2013 to 2017. However, in 2017 a shutdown occurred. As a consequence, in combination with a long period of drought, a significant decrease of 9% in usable water consumption occurred. The last water supplier, SMAS Sintra, contributed between 0.2% and 1% of total water entering Cascais in the years 2013 to 2017 (Cascais water matrix, 2019).

As can be seen in the *proportion of the main components of the water balance supply system,* of the total percentage of water entering, 84 to 87% is consumed by the population. The remaining water does not reach the consumer's taps. Leaks and breakages can explain this loss in the pipes. This type of loss is called apparent water loss. Another loss can occur in the reservoir, which is described as actual losses. In the reservoir water is removed illegally from the system for unauthorized use. Other possible reasons for water losses can be water measuring errors or errors in data processing and handling systems (Cascais water matrix, 2019). The sum of the illicit uses and losses of water due to measurement errors constitutes the apparent losses of the Municipality. Real losses in the Cascais system in the years 2013 to 2017 represent around 6% of the water entering the system. This loss adds up to a maximum of 1.4 million m3 of water a year.

Moreover, when looking at the performance of Cascais relating *Apparent Water Loss and Actual water loss* the company Águas de Cascais shows good results, always presenting values below the reference value proposed by ERSAR, which corresponds to 20%. This 20% can be seen as a minimum threshold for good performance. Furthermore, the percentage of non-billed water is also below the national average of 30%. However, there is still much to be done in this area. The view *Actual water loss per supplier* can help identify trends of water loss between the three main water suppliers of Cascais. This information can provide a tool for a city manager redirect focus to achieve real change.

Moreover, the view *volumes of water supplied, and volumes of wastewater produced in Cascais* shows that the annual wastewater production in Cascais during the period under review ranged from 14.9 to 20.9 million m3 (Cascais water matrix, 2019). However, the variation in the volume of water wastewater sent for treatment does not follow the same trend of variation in the volumes of water that entered the Cascais water supply system for human consumption. In the years 2013, 2014 and 2016, the volumes of wastewater exceeded the volumes of water for human consumption, in 2015 and 2017, which are also the years of drought, the trend is opposite. The use of water could explain the lower inflow of wastewater into the drainage system for outdoor purposes, such as watering outdoor spaces, which is increasingly necessary for periods of drought.

5. CONCLUSION

The objective of this project report was to identify and assess relevant indicators that follow the current state of a municipality's water management system. Moreover, this paper used the design research methodology intending to create a conceptual model of a monitoring system that displays these identified indicators. Contemporary problems in water management are characterized by increasing complexity. Climate change creates new uncertain challenges to tackle. Therefore, the need arises for cities to implement monitoring systems with clear indicators, clean data, set targets and goals to achieve their long-term sustainable development plans successfully.

The Municipality of Cascais was looking for someone to support this initiative, while they currently do not have this type of dashboard for monitoring purposes. Moreover, this initiative is very in line with the character of the Municipality, as they are increasingly focused on improving their sustainable practices. Therefore, the Municipality of Cascais became the ideal candidate to start a project with this sort.

This project is executed following the design science research methodology and passed all phases to obtain the final result of the project, namely the dashboards.

The idea of the report was to enrich existing literature on relevant indicators while adding value to the Municipality itself with a monitoring system that they can use every week. Unfortunately, due to external complications, the Municipality of Cascais was not able to collect and to centralize the necessary data to create the metrics and simultaneously the dashboards. As an alternative, I collected historical data from the year 2013 to 2017 from the Cascais water matrix. While this data is hand-picked and created it purely serves as a mean to support the dashboards. The dashboards are useful to navigate through the data, obtain details, various points of view and comparisons, by using filters and drill down the data. Next to that, the dashboards contain the most relevant. However, various indicators to expand the city managers' vision and for them to gain more knowledge about how the Municipality is performing through the years.

The mock-up dashboards have been collected, evaluated and approved by the Municipality. My contact person within the Municipality accepted the solution and plans on using the mock-up dashboard as a project to implement in the future. While the collection of views is inlign with the collection of indicators that I wanted to visualize, I believe that the most important addition to the dashboards is the ability to show water data on a day, week and month level. With this addition to the dashboards, the Municipality, as well as the citizens of Cascais, can perform relevant and effortless analysis. Hopefully, the dashboards, with the addition of data, will be in full use.

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7. APPENDIX

APPENDIX A: CASCAIS ACTION PLAN

No.	Measure	Actions
2	The separation of wastewater and rainwater	1. Undue flow management plan 2. Building surveys km/year 3. Video inspection (CCTV) 4. Tests with a smoke generating machine 5. Monitoring of flow conditions 6. Monitoring the correction of anomalies 7. Stormwater Wastewater Improvement
4	The identification of alternatives to the provision of drinking water	1. Implementation of the 3rd EDF Adductor 2. Implementation of the Upper Reservoir 3. Refurbishment of the Treatment Plant for Mula river water 4. Refurbishment of the elevating system of the Pisão Alcoitão 5. Maintenance of the Funding 6. Management Programme Losses and Energy
6	The elimination of pollution in water lines	1. Refurbishment Water Collectors Domestic Residuals 2. NE building surveys 3. Inspection with camera CCTV (video) 4. Maintenance plan network prevention domestic wastewater 5. Cleaning of pits V 6. Monitoring the correction of anomalies identified in networks property

Table 9 - Overview of water-related goals and actions

APPENDIX B: INDICATORS WATER MATRIX CASCAIS

Indicator	Unit
Drinking water that enters the Cascais supply system	*m3/year*
Percentage of water that comes from the EPAL adductor system	*%*
Uninvoiced water	*m3/year*
Water losses	*%*
Authorized consumption	*%*
Number of repaired leaks and number of leaks per 10 km	*number/ 10 km*

Table 10 - Water supply indicators

Indicator	Unit
Percentage of non-domestic water consumption	*%*
Amount of water consumption	*m3/year*
Number of non-domestic consumers	*n*
Percentage of domestic water consumption	*%*
Average domestic water consumption per day	*litres/cap/day*
National average domestic water consumption per day	*litres/cap/day*
Increase in consumption in drought years	*litters/year*
Water consumption of the Cascais Municipal Council	*litres/year*

Table 11 - Water consumption indicators

Indicator	Unit
Amount of treatment wastewater	*m3/year*
Amount of appropriate treatment for reuse	*m3/day*
Total amount of water produced for reuse	*m3/year*
Total amount of wastewater produced	*m3/year*
Reused water consumed by Cascais Ambiente	*m3/year*
Reused water consumed by Guia's treatment plant	*m3/year*
Number of deficiencies identified, and length of net inspected	

Table 12 - Drainage and wastewater treatment

Indicator	Unit
Water requirements of Cascais	*m3*
Maximum local water resources	*m3/year*
Reduction in water consumption	*%*
Self-sufficiency	*%*

Table 13 - Water balance

APPENDIX C: DATA

dicofre	nutsI	NUTSI_COD	nutsII	nutsII_code	nutsIII	nutsIII_code	district	municipality	parish
30102	CONTINENTE	1	NORTE	11	CÁVADO	112	BRAGA	AMARES	BARREIROS
30104	CONTINENTE	1	NORTE	11	CÁVADO	112	BRAGA	AMARES	BICO
30105	CONTINENTE	1	NORTE	11	CÁVADO	112	BRAGA	AMARES	CAIRES
30107	CONTINENTE	1	NORTE	11	CÁVADO	112	BRAGA	AMARES	CARRAZEDO
30108	CONTINENTE	1	NORTE	11	CÁVADO	112	BRAGA	AMARES	DORNELAS
30111	CONTINENTE	1	NORTE	11	CÁVADO	112	BRAGA	AMARES	FISCAL
30112	CONTINENTE	1	NORTE	11	CÁVADO	112	BRAGA	AMARES	GOÃES
30113	CONTINENTE	1	NORTE	11	CÁVADO	112	BRAGA	AMARES	LAGO
30118	CONTINENTE	1	NORTE	11	CÁVADO	112	BRAGA	AMARES	RENDUFE
30119	CONTINENTE	1	NORTE	11	CÁVADO	112	BRAGA	AMARES	BOURO (SANTA MARIA)
30120	CONTINENTE	1	NORTE	11	CÁVADO	112	BRAGA	AMARES	BOURO (SANTA MARTA)
30125	CONTINENTE	1	NORTE	11	CÁVADO	112	BRAGA	AMARES	UNIÃO DAS FREGUESIAS DE AMARES E FIGUEIREDO
30126	CONTINENTE	1	NORTE	11	CÁVADO	112	BRAGA	AMARES	UNIÃO DAS FREGUESIAS DE CALDELAS, SEQUEIROS E PARA
30127	CONTINENTE	1	NORTE	11	CÁVADO	112	BRAGA	AMARES	UNIÃO DAS FREGUESIAS DE FERREIROS, PROZELO E BESTE

Dimension table - Parish

supplier	supp_water_supply	author_water_supply	app_water_loss	actual_water_loss	year	water_entering
EPAL	1,78	13,4769	1,2	0,5	2013	83,5
Municipality	0,1	2,53398	0,6	0,3	2013	15,7
SMAS Sintra	0,02	0,14	0,12	0,15	2013	0,8
EPAL	1,67	12,36288	1	0,5	2014	82,2
Municipality	0,07	2,64704	0,6	0,2	2014	17,6
SMAS Sintra	0,01	0,06	0,25	0,01	2014	0,2
EPAL	1,13	12,9344	0,9	0,9	2015	86,2

Fact table - Waterbalance

parish	water_consumption_per habitant (m3/hab.ano)	year	non_dome	water_consumption (mln m3)
ALCABIDECHE	67	2013	0,9	2,8
UNIÃO DAS FREGUESIAS DE CASCAIS E ESTORIL	105	2013	2,2	6,5
SÃO DOMINGOS DE RANA	56	2013	0,7	3,2
UNIÃO DAS FREGUESIAS DE CARCAVELOS E PAREDE	67	2013	0,7	3
ALCABIDECHE	63	2014	0,8	2,7
UNIÃO DAS FREGUESIAS DE CASCAIS E ESTORIL	104	2014	2,3	6,4
SÃO DOMINGOS DE RANA	55	2014	0,7	3,2
UNIÃO DAS FREGUESIAS DE CARCAVELOS E PAREDE	68	2014	0,7	3
ALCABIDECHE	65	2015	0,9	2,8
UNIÃO DAS FREGUESIAS DE CASCAIS E ESTORIL	114	2015	2,7	7,1
SÃO DOMINGOS DE RANA	56	2015	0,7	3,2
UNIÃO DAS FREGUESIAS DE CARCAVELOS E PAREDE	68	2015	0,8	3,1

Fact table - Consumption

year	wastewate	wastewate	mun_wate	mun_treat	reused_eta	wastewate
2013	20	750	1,1	0	0	18
2014	21	780	1,09	0	130	16,5
2015	14	500	1,18	5,9	160	17
2016	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]

Fact table - Wastewater

APPENDIX D: DATA MODEL