NOVA IMS Information Management School

MGI

Mestrado em Gestão de Informação
Master Program in Information Management

360º Data Visualization Dashboard

Cascais Smart City

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

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360º DATA VISUALIZATION DASHBOARD

by

José Maria Rebello de Andrade Estevens

Project work presented as a partial requirement for obtaining the Master's degree in Information Management, with a specialization in Knowledge Management & Business Intelligence

January 2022

ACKNOWLEDGEMENTS

To my family and friends for being patient, always wanting what's best for me and never letting me give up. To my advisor, Professor Dr Miguel Neto for all the assistance in doing this project. And to Engª Benigna Moreira Lima Pereira, who gave all the help in the world in developing this project and to who I express my sincerest gratitude.

ABSTRACT

In recent years, Cascais cemented itself as a top 10 Smart City globally, drawing the attention of many cities willing to embark on the same path. However, Cascais still has its' shortcomings, mainly regarding the monitorization/supervision of its' many smart city themes. This project is then based on building dashboards with relevant data to aid in the smart city area of Cascais. With these dashboards, the goal is to provide detailed information and metrics regarding the current status and performance of all citywide themes discussed in further detail later on. Residents, tourists and city workers alike can use the dashboards to learn about the performance of their city and its' many varied aspects

KEYWORDS

Smart City; Business Intelligence; Optimization; Dashboard; Cascais; 360º View; CITYkeys

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1. INTRODUCTION

This project will be developed in Cascais, being my place of residence and known for its' climate and coastlines filled with natural landscapes and beaches. It is in the top 5 most populous urban areas in Portugal.

Being a Smart City, Cascais is constantly looking for more practical and efficient approaches to benefit its' community. Thus, the intelligent use of technology is vital and regarded as the main objective of upcoming projects, alongside Cascais' citizens' feedback and cooperation.

Cascais creates a very big amount of information to aid in the management and planning of the city, providing knowledge about its' location and inhabitants. Therefore, a framework to show this data must be developed. Said data is primarily open, meaning that anyone can use it for any purpose.

Many dashboards will be created to analyze various themes around Cascais, all while following a dashboard framework with many indicators to reach relevant conclusions to aid in future decision-making for Cascais.

1.1. STUDY GOALS

For this project, the purpose is to build dashboards to assist Cascais' city hall in analyzing performance in Cascais to help in the decision-making process and the creation of future smart city initiatives.

For that purpose, the following steps must be taken:

- Research what are considered the optimal practices for performance measure visualization concering dashboards;
- Select the indicators that are more suited to the study of the performance of the smart city;
- Select and prepare the appropriate data;
- Build and analyse the results obtained in the dashboard.

1.2. METHODOLOGY

For this project, the process will begin with the planning and definition of the methodology, followed by the literature review.

Once the literature review is finished, a planning phase will commence with data selection, indicator definition, and mockups, which is the best way to explore visual decisions beforehand.

With the planning phase concluded, the project will now advance towards creating and implementing the final versions of the dashboards, followed by result evaluation in which the data is monitored. The dashboards are analyzed to see if they are capable of accomplishing their purpose and defined goals.

According to Peffers et.al (2007), in order to have a proper design science research methodology, six crucial steps must exist:

- Identify and motivate the problem;
- Define the objectives for a determined solution;
- Design and develop said solution;
- Demonstrate the solution;
- Evaluate the solution;
- Communicate the solution.

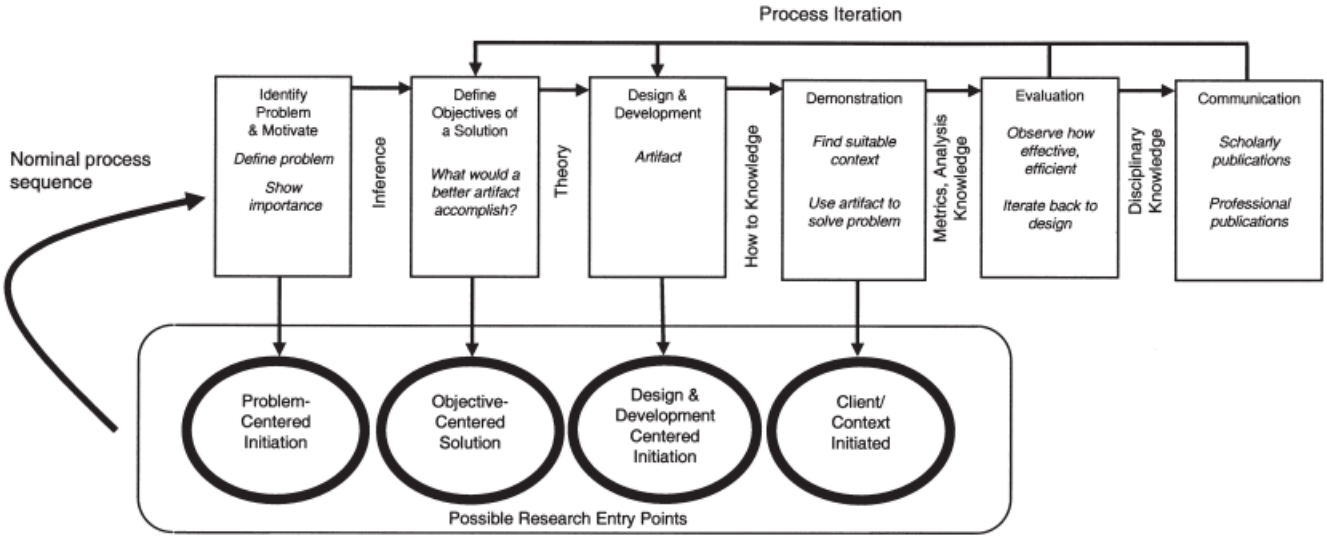


Figura 1 - Design Science Research Methodology Model, taken from the article "A Design Science Research Methodology for Information Systems Research" written by Peffers et.al (2007)

2. LITERATURE REVIEW

In this chapter, and to serve as a theoretical basis for the project, a literature review will be done. Initially, the literature review will show a comprehensive description of the meaning of a smart city and its' models.

Additionally, the literature review will also present the open data portal in Cascais, alongside its' goals and main features.

To conclude, the need for dashboarding will be presented with its' best practices and objectives.

2.1. DEFINITIONS OF A SMART CITY

The attempt at defining a "smart city" is a topic that is becoming more discussed in literature. According to Mori and Christodoulou (2012), cities are very important in social and economic aspects around the world and their impact is heavily felt in the environment.

At the moment, there are several definitions of “smart city”, which is why in some areas there is some inconsistency in its’ definition. According to O'Grady and O'Hare (2012), there is no single correct way to define a smart city.

With that being said, the table below will show some definitions made by popular authors in the smart city context:

Definition	*Source*
“Being a smart city means using all available technology and resources in an intelligent and coordinated manner to develop urban centers that are at once integrated, habitable, and sustainable.”	Barrionuevo et al. (2012)
“A smart city is a high-tech intensive and advanced city that connects people, information, and city elements using new technologies to create a sustainable, greener city, competitive and innovative commerce, and an increased life quality.”	Bakici et al. (2012)
“A city that monitors and integrates conditions of all of its critical infrastructures, including roads, bridges, tunnels, rails, subways, airports, seaports, communications, water, power, even significant buildings, can better optimize its resources, plan its preventive maintenance activities, and monitor security aspects while maximizing services to its' citizens.”	Hall (2000)
“Smart cities as territories with a high capacity for learning and innovation are built in the creativity of their population, their institutions of knowledge creation, and their digital infrastructure for communication and knowledge management”.	Komminos (2011)
“Smart cities have high productivity as they have a relatively high share of highly educated people, knowledge-intensive jobs, output-oriented planning systems, creative activities, and sustainability-oriented initiatives.”	Kourtit et al. (2012)

2.2. SMART CITY MODEL

According to Dirks and Keeling (2009), it is necessary that a smart city has its' many themes integrated. Towards that end, researches found it easier to "split" smart cities into different dimensions.

In the beginning of this study, Giffinger et al. (2007) managed to identify four aspects that are in a smart city:

- Industry of a smart city;
- Education of a smart city;
- Participation;
- Technical infrastructure of a smart city.

Since then, the number of aspects has increased to six, which are the following (Giffinger and Gudrun, 2010):

Smart City components	A related aspect of urban life
Smart Economy	Industry
Smart People	Education
Smart Governance	E-democracy
Smart Environment	Efficiency & Sustainability
Smart Mobility	Logics & Infrastructures
Smart Living	Security & Quality

Table 1: Components of a smart city and related aspects (adapted from Lombardi et al., 2012)

According to Currid (2006), smart cities constitute the main innovation that influence the worlds' economic development.

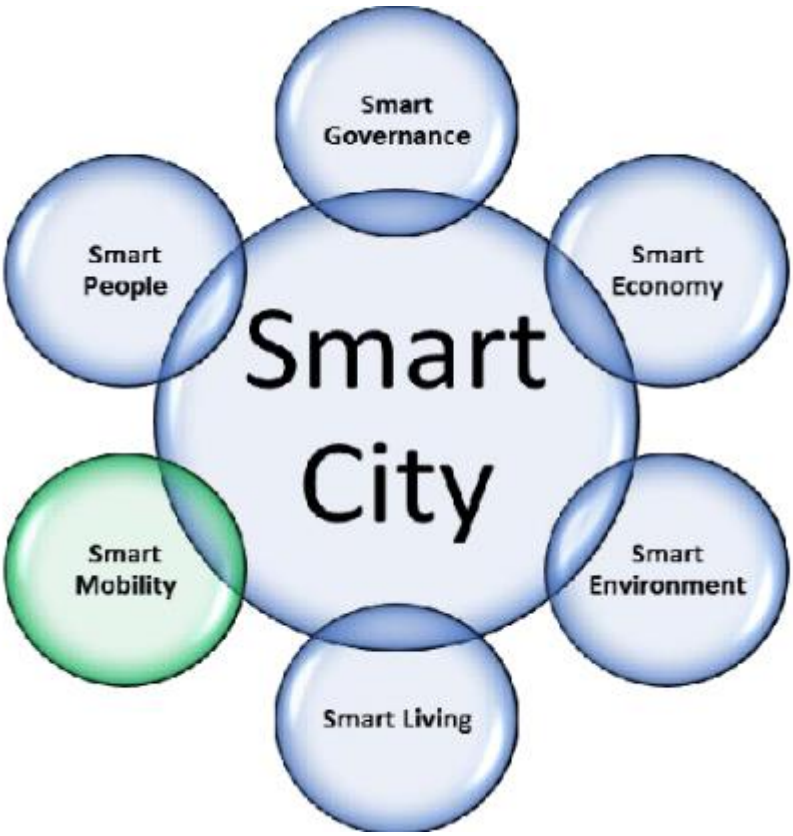


Figura 2 - Smart City Model, taken from the article "Identification of significant metrics and indicators for smart mobility Methodology for Information Systems Research" written by Giffinger and Gudrun (2010)

2.3. VISUALIZING DATA

There was a need to display large amounts of data in a readily accessible and understandable way. Since organizations create data daily, the quantity on the Internet has increased exponentially. Thus, it is difficult for users to take advantage of data to its full extent, hence the great importance of visualizing data. (Mallon, 2015).

According to Sancho (2014), humanity has always used visuals to perpetuate information. In his own words, "what cannot be touched, smelled, or tasted can be represented visually". (Sancho, Dominguez, et al., 2014).

In summary, we can define data visualization as a powerful tool for analyzing and interpreting large and complex amounts of data. Because of this, data visualization is important to many fields of study.

2.3.1. Visualization Techniques

When building dashboards, there are many different ways to visualize and represent data, as seen in the figure below:

Figura 3 - Dashboard Visualization Techniques, taken from an SAS article

As we can see, there are many different usable visualization techniques. However, this study will be focused on the most common methods, which are:

- **Line Graph**;
- **Bar Chart**;
- **Scatter Plot**;
- **Pie Chart**.

According to an article written by SAS, the use of colors is very important when it comes to visualization. When talking about data visualization, colors must be used carefully in order to correctly distinguish different data elements.

2.3.2. Applications & Challenges

According to Mahmoud(2019), data visualization has many application areas. Some examples of said application areas are the following:

- Public Health;
- Renewal Energy;
- Environmental Science;
- Fraud Detection;

Rizik (2019) states that large datasets pose a big challenge for data visualization because of their size. Not all data users have the same ability to use data visualization to their benefit and are forced, because of this, to make decisions under tight schedules. This happens because it's difficult to evaluate what is the best data visualization technique.

According to Li, big data, regardless of type, poses a unique set of challenges in the process of constructing visualizations since the data's speed, size, and diversity must be considered. Some issues that tend to arise when working with big data usually relate to performance and usability.

2.4. CONSTRUCTING A DASHBOARD

In these past years, dashboards have become the standard tool when talking about data visualization. Moreover, lots of new dashboard solutions have been created in order to respond to the high demand. However, there hasn't really been given any attention on how to design thoughtful and easy to use dashboards ("A Guide to Creating Dashboards People Love to Use," 2009). With that in mind, in this study we will go over the three optimal steps we should take when creating a dashboard:

- **Foundation;**
- **Structure;**
- **Information Design.**

2.4.1. Foundation

According to the book "A Guide to Creating Dashboards People Love to Use" (2009), dashboards must first have an audience in mind before being built:

- Who will use the dashboard?
- What do they need from the dashboard?
- What information are they already aware of?
- What are their qualities and flaws?

The issue with this is that most dashboards tend to have multiple possible audiences. Because of this, prioritizing audiences so conflicts can be more easily handled is necessary. ("A Guide to Creating Dashboards People Love to Use," 2009).

	Questions	Implication
Role	What decisions do they make? What questions do they need answered?	Structure the information to make it super easy to answer high priority questions.
Work flow	In what context will they be reviewing the dashboard? What information are they using on a daily basis? How much time do they have to review the numbers?	The form and information display needs to fit into an existing work flow. For example, an on-the-road sales person may need information delivered to her BlackBerry, not designed for an online wide-screen monitor.
Data comfort and skills	How sophisticated are they with using data? Are they proficient in Excel? Do they enjoy digging into the numbers?	The dashboard's level of detail and analytical capabilities should match the audiences' comfort zone.
Business and data expertise	How familiar are they with the key performance metrics? Do they understand where the data comes from? Are they familiar with internal company or industry terminology?	This determines the need for embedded explanations and use of natural language.

Table 3 – Dashboard Foundation, according to "A Guide to Creating Dashboards People Love to "Use, 2009

According to Rowan (2020), information is included in a dashboard often when someone in a position of influence finds it interesting. However, that poses the following question: Will the information drive productive action? The strategies below will assist in filtering the information down to the one that really matters ("A Guide to Creating Dashboards People Love to Use", 2009):

- **Find the Core** – Any dashboard must have a theme behind it, instead of just data on a screen.
- **Ask the right questions** – If we fail to ask the right questions, the dashboard will suffer in quality when it's time to perform analyses.
- **Create an appendix** – When there are many requests for information, one option we can take is create an appendix that has the information required but maintains the focus on the most important data;
- **Reporting vs. Exploration** – A dashboard can't be a generic tool nor can it be built to answer a new question that might come in the future. If there is a request for information that is

outside the territory of analysis, that is an issue with the request and not with the dashboard.

2.4.2. Structure

The critical aspect of selecting a form for the dashboard is to choose the one is best suited for the situation. The main goal of a dashboard is to show information to users so that it can be understood, delivered when and where the user needs the information.

The following factors may influence the form of the dashboard ("A Guide to Creating Dashboards People Love to Use,2009):

- **Timeliness –** How many times is the data present in the dashboard updated?
- **Value –** Does a dashboard need to look good or can it be purely functional?
- **Mobility –** Can a user access the information on the fly?
- **Connectivity –** Are there any data sources that the dashboards need to connect to?
- **Data Detail –** Can we drill down the data to obtain more context on the situation?
- **Data Density –** How rich will the data be visualized in our dashboard?
- **Interactivity –** How interactive is the dashboard to the user and how will he benefit from it?
- **Collaboration –** Is it important that our users can share and edit the dashboard easily?

	Paper One-pager	Paper Presentation	Excel	Online app	E-mail / text message	Large screen
Timeliness	-	-	+	+	+	+
Aesthetic	+	+		+	-	+
Mobility	+				+	-
Connectivity	-	-		+	+	+
Data detail	-	+	+	+	-	
Data density	+	+			-	
Interactivity	-	-		+	-	-
Collaboration					+	-

Figura 4 - Dashboard Structure, according to "A Guide to Creating Dashboards People Love to Use", 2009

In order to correctly structure a dashboard, we must have a deep understanding of how the system works. The best model for our dashboard will depend on the specificity of the problem. That being said, dashboards tend to fall into three categories ("A Guide to Creating Dashboards People Love to Use, 2009):

- **Flow** – Sequence of events or actions across time;
- **Relationships** – The relationships between entities or measures;
- **Grouping** – Putting things that present similarities together in the dashboard.

2.4.3. Information Design

2.4.3.1. Interface Design

According to "A Guide to Creating Dashboards People Love to Use" (2009), many websites share the same goal of dashboards: to limit unneccessary clutter in order to allow users to easily access and understand the information that is provided. With this in mind, that are many ways that can be implemented in order to meet this goal, such as:

- Page organization;
- Colour;
- Typography;

Starting with page organization, we will want to organize the most important information where users tend to look first. "A Guide to Creating Dashboards Love to Use" (2009) tells us that users tend to look at the information that is displayed on the top left first, as we can see in the following figure:

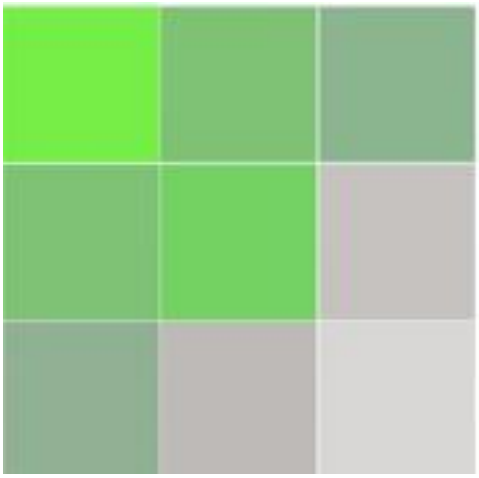


Figura 5 - Dashboard ideal Heat Map, according to "A Guide to Creating Dashboards People Love to "Use, 2009

Moving on to color, it can be used to push us towards what is most important in our dashboards and it also aids in the grouping of similar items. One practical example of this is that if we increase color brightness on a specific area in our dashboard, our attention will go towards it and make it look urgent. In a similar way, using the same color on different items will connect them on our dashboard since they are most likely related (“A Guide to Creating Dashboards People Love to Use“ ,2009).

Figura 6 - Dashboard colors, according to “A Guide to Creating Dashboards People Love to “Use, 2009

Going further in detail, when it comes to representing data, we can consider three different color schemes(“A Guide to Creating Dashboards People Love to Use“ ,2009):

- **Sequential;**
- **Divergent;**
- **Categorical.**

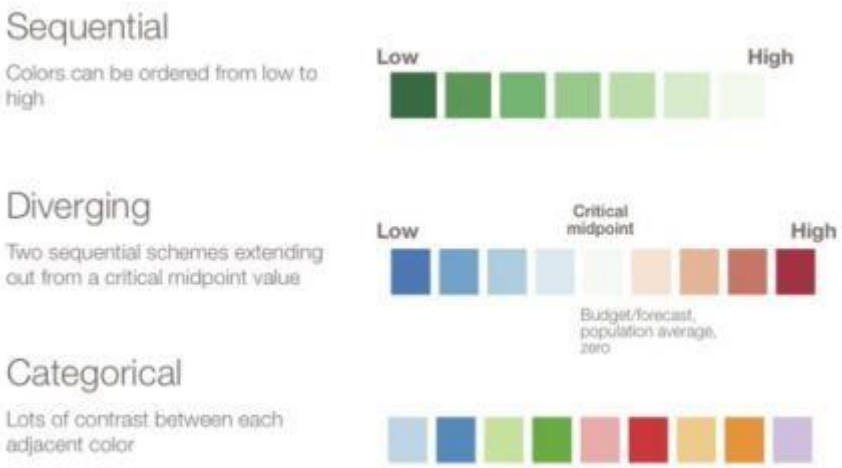


Figura 7 - Dashboard color schemes, according to "A Guide to Creating Dashboards People Love to "Use, 2009

When it comes to the font, there are four main categories that we can consider("A Guide to Creating Dashboards People Love to Use" ,2009):

- **Body** – The text presented has to be easy to read;
- **Headers** – They must be used to separate different parts of the text;
- **Notes** – Used to provide additional tidbits the reader can benefit from knowing;
- **Emphasis** – The text presented must hold our user's attention throughout it.

	Purpose	Size	Font	Color	Style
Body	Clean readable text, 50-80% of your text will look like this.	10-16pts	sans-serif: Arial, Tahoma, Verdana serif: Georgia, Times	Neutral	Normal No bold, no italic 1.2 line spacing
Header	Separate and name major sections of your writing.	150–200% of **body**	Same as **body** or flip serif/sans-serif	Neutral	Normal, bold, or italic Whitespace above
Notes	Additional things a user should be aware of, data sources, metric calculations. "Fade into the background"	85% of **body**	Same as **body**	De-emphasized, lower contrast	Normal No bold, no italic
				Choose one or both	
Emphasis	Draw the eye to key points you need to make.	Same as **body**	Same as **body**	High impact color	Bold or italic

Table 4 – Dashboard Typography, according to "A Guide to Creating Dashboards People Love to "Use, 2009

2.4.3.2. Information Display

In order to choose the correct chart or table, we must first understand data types and chart types to answer. There are two major types of data(“A Guide to Creating Dashboards People Love to Use“ ,2009):

- **Categorical;**
- **Quantitative;**

	Meaning what?	Examples
Categorical (dimensions)		
- Nominal	The ordering of the values has no intrinsic meaning	Department (HR, Sales, Operations, ...), US States
- Ordinal	Ordered, "Every value has a place"	Months of the year, grades in school, tenure with employer
- Time Series	Dates and times	2009Q1,2009Q2, ..., June 9, 2009, June 10, 2009, ...
Quantitative (measures)		
- Additive	Adding values makes sense, zero is meaningful	Total employees, market share
- Non-additive	Only differences in values makes sense	Blood pressure, temperature

Figura 8 - Dashboard Data Types, according to “A Guide to Creating Dashboards People Love to “Use, 2009

To complement this, we can also add the following:

- Use charts that maximize user comprehension;
- Be truthful with the data.

2.5. BI – BUSINESS INTELLIGENCE

According to Elena, Business Intelligence, as it is understood today, stems from decision support systems that first originated in the 60s and that were developed through the 80s.

BI can be incorporated in the following businesses to drive business value:

- Measurement;
- Analytics;
- Reporting;
- Collaboration;
- Knowledge Management.

Prof. Dr. Ralph Kimball explains that a business's needs stand at the epicenter of it's core. Business requirements analysis occur at both these stages:

- **Macro-Level** – With a perspective given on a program, comprehend its' business requirements and main objectives;
- **Micro-Level** – In the context of a single project, comprehend what are the users' wishes.

2.5.1. BRIEF HISTORY OF BI

According to Heinze, Business Intelligence is a concept that existed long before technology.

In Richard Miller Devens' 1865 work *Cyclopaedia of Commercial and Business Anecdotes* we can read for the first time term "Business Intelligence": **"Throughout Holland, Flanders, France, and Germany, he maintained a complete and perfect train of business intelligence."**

In 1958, an article written by Hans Peter Luhn, called "A Business Intelligence System," had the following quote: **"an automatic system… developed to disseminate information to the various sections of any industrial, scientific, or government organization".**

In essence, Hans Peter Luhn pretty much defined what B.I. Is: a method to easily comprehend vast amounts of information in order to find the optimal solution and further decision-making.

Due to his contributions to BI, Hans Peter Luhn is now known as the "Father of Business Intelligence."

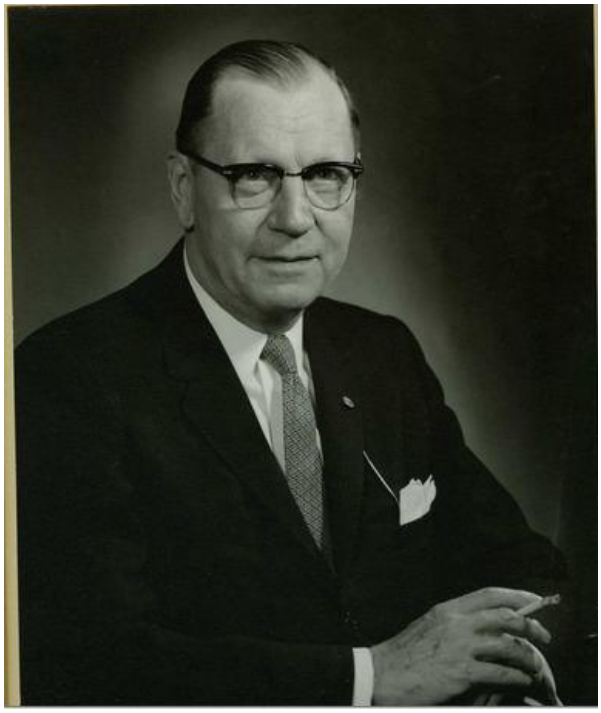


Figura 9 - Hans Peter Luhn

2.5.2. ETL PROCESSES

According to Sonali & Vaishnav(2017), data in a data warehouse is loaded only after doing all three operations of the ETL process, which are the following:

- Extraction;
- Transformation;
- Loading.

In the following chapters, we will go more in depth with each phase of the ETL process.

2.5.2.1. EXTRACTION

Sonali & Vaishnav (2017) state that, in this process, data is extracted from one or more sources, such as applications or database systems. Said process must be built so that it doesn't affect performance or response time. According to Sonali & Vaishnaw (2017), there are two extraction methods:

- Logical Extraction;
- Physical Extraction.

2.5.2.2. TRANSFORMATION

In the transformation process, Sonali & Vaishnav (2017) state that in this step, the data is transformed so that it can placed in a data warehouse. However, before we can do that, we must also apply data correction, data cleansing, removal of inaccurate or duplicate items and fix possible errors in the data.

2.5.2.3. LOADING

In the final ETL process of loading, Sonali & Vaishnav (2017) state that, here, data is stored into the dimensions that will be accessed by our end users and applications. It is crucial that the data load is performed correctly and with as less resources as possible.

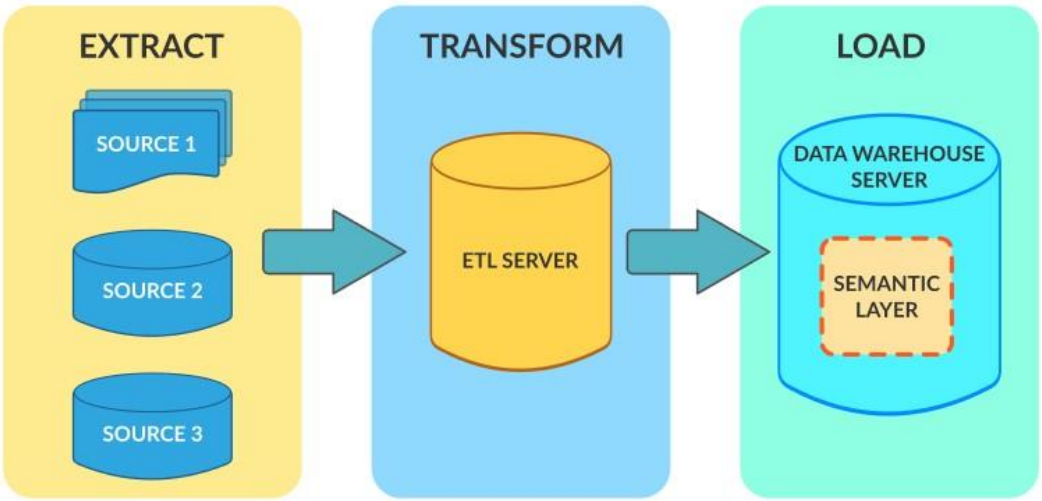


Figura 10 - ETL Process, taken from customizewindows.com

2.6. 360º SMART CITY

In short, a 360º smart city is a perspective that allows the municipality to control the main variables that integrate the functions of a city, namely, the environment, public lighting, security, traffic, communication channels, parking lots, among many other infrastructures.

According to Rana Sen, a managing director in Deloitte, a 360-degree view smart city includes every dimension of a smart city and improves the decision making process with the use of technology.

It is a common occurence that in a smart city, there is a platform/app that citizens can access to provide feedback and reports about the city. This platform serves as the main bridge of communication between citizens and their city's municipal services.

There already are many examples of a 360-degree view incorporated in a smart city to help in the immediate response to customer needs. In the following chapters, we will go over a few of them.

2.6.1. CASE STUDY – ALBUFEIRA

Today, Albufeira is a smarter city, in large part due to the to the development of the online app "Albufeira Smart City – Gestão de Ocorrências", an easy user-friendly app that allows citizens to communicate with the autarchy.

With this solution, it is now possible to directly respond to the needs and problems of Albufeira's citizens, managing their resolution efficiently, since all occurrences go straight to their Smart City department in their town hall.

Apart from customer feedback, information is also gathered through sensoring devices scattered throughout the city, which is then immediately analyzed and looked at to solve potential problems or attend to customer needs.

In short, this platform allows the autarchy to control all of the city's themes and its' many variables and functions. This is the beginning of an ambitious digitalization process, which will be evolutionary to make the municipality of Albufeira increasingly efficient in the management of its territory and the service provision for its' citizens.

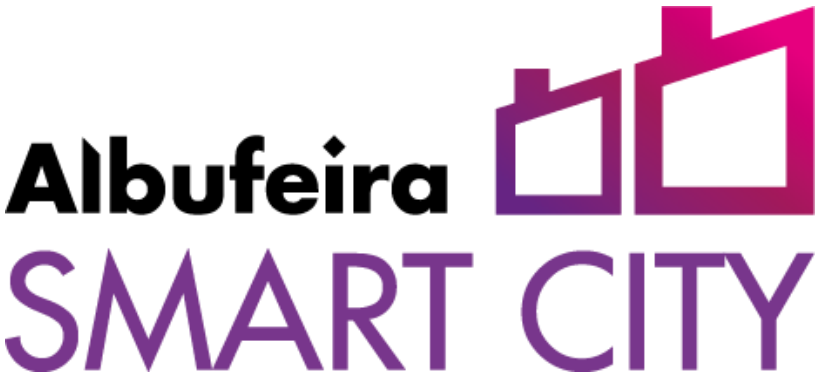


Figura 11 - Albufeira Smart City Logo, taken from their data portal http://smartcity.cm-albufeira.pt

2.6.2. CASE STUDY – FAMALICÃO

In June 2021, Vila Nova de Famalicão took a massive leap towards its' digital affirmation with the presentation of Smart City Famalicão – an urban intelligence platform developed in partnership with NOS, which aggregates the municipality's intelligent management tools.

Included in the B-Smart Famalicão project, an initiative to turn Vila Nova de Famalicão into a greener, more inclusive, and smarter city, this new platform materializes in an Urban Control Center, which processes, analyzes, and compares information collected through the sensing devices present throughout the city, autarchic information collected by municipal services and integrated information from national institutions and universal technological tools.

It is possible, as a practical example, to verify and compare data on accidents and civil protection in the county, municipal interventions carried out in the territory over the years in various fields, such as Asian wasp nests, burnings being carried out in the county duly authorized, among many other data that can be consulted and analyzed. It is also possible to understand the distribution and precise location of the network of recycling points throughout the municipality and the sanitation and water network that runs through the municipality.

This platform, which is available for public consultation through the municipality's portal, monitors and provides to the citizen a vast set of urban indicators in the municipality in an exercise of great transparency and public utility, while also facilitating institutional responses in areas such as civil protection, public hygiene, mobility, among others, enabling the activation of the necessary responses to deal with any possible occurrences.

Figura 12 – B-Smart Famalicão logo, taken from their website http://b-smart.famalicao.pt/

3. DASHBOARD DEVELOPMENT

As previously stated in the methodology, the development of this project will follow the design science research methodology model. So, an initial proposal must be made to begin said process that will result in the implementation of dashboards and, ultimately, to its' results' analysis, bringing the project to a close.

3.1. PERFORMANCE MEASUREMENT FRAMEWORK BENCHMARKING

When we talk about dashboards, it is common practice to do a benchmarking process to compare the many different performance measurement frameworks to figure out which one works best for a particular study. In this specific case, such a process will not be necessary due to the very nature of our performance measurement framework chosen – CITYkeys.

CITYkeys, at its' core, is already a combination of 43 existing indicator frameworks. Therefore, the benchmarking process was already done to create this framework and, due to this, it is no longer necessary to compare it with existent frameworks that might have already contributed to its' development.

Having said that, in the next section we will go more in-depth into what CITYkeys is and its' many indicators and benefits.

3.2. THE CITYKEYS PERFORMANCE MEASUREMENT FRAMEWORK

According to Bosch, the development and implementation of smart city projects is a major factor, when we talk about the three P's indicators, with them being people, planet and prosperity, respectively (Fortune and White, 2006). Hiremath et al. (2013) also notes that Governance related indicators have been identified as one of four pillars of sustainability.

By using the CITYkeys methodology, cities will gain many benefits such as:

- The ability to plan and measure progress towards reaching a specific smart city goal;
- Allowing citizens to voice their needs and have them properly addressed;
- Optimizing usage of a smart city's budget;
- Comparing solutions and finding best practices between other smart cities.

Figura 13 – CITYKeys logo

3.3. INDICATOR SELECTION PROCESS

In this section, we will select the indicators best suited for our smart city project. Towards that aim, the CITYkeys methodology will assist in the benchmarking process and resulting indicator selection. (Bosch et al., 2017).

The CITYkeys methodology will be used to help evaluate the possibility of it being replicated in other possible situations. According to Bosch (2017), a successful methodology can be determined by the size and influence of the ecological footprint in a smart city.

The CITYkeys' framework is at its' core comprised of 43 other frameworks. Moreover, the large majority of the indicators present in this framework are pulled from other frameworks.

In this process, we will look at five major themes that will be presented below:

Figura 14 - CITYkeys Smart City Themes

As we build our dashboards, we will fit them inside the proper themes, as seen in the figure above.

Firstly, we will "filter" the indicators by removing those not present in our data portals. After that, we can then choose which indicators we find are the most relevant for our model.

3.4 SMART CITIES IN THE WORLD

Since Cascais is the smart city that we are covering in this study, we will analyzed other relevant cities in Europe and how is their performance in the themes previously mentioned. The results covered in this section are the work of a study done by Manville et al. (2014), with the aid of a database that has information on all other cities that have at least one hundred thousand citizens.

To be considered an eligible city for this study, Manville et al. (2014) stated that a smart city needs to have at least one of the six themes previously mentioned. After the data collection process, the authors decided that the requirement for being included in the study for a smart city is to have at least one of the six characteristics.

After said process, some conclusions were made:

- The number of small smart cities is bigger than the number of large ones.

- Larger cities hold the most significant resources and, because of this, have better and more progressive smart city initiatives.

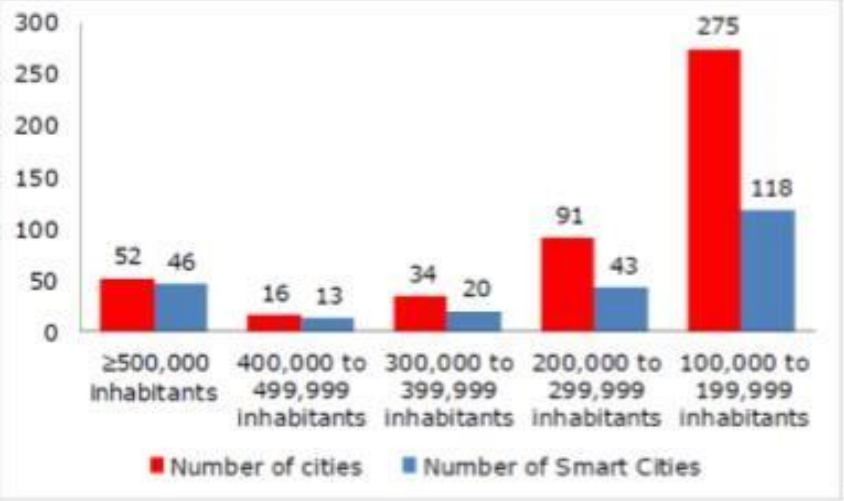


Figura 15 - Cities vs Smart Cities, according to Manville et al. (2014)

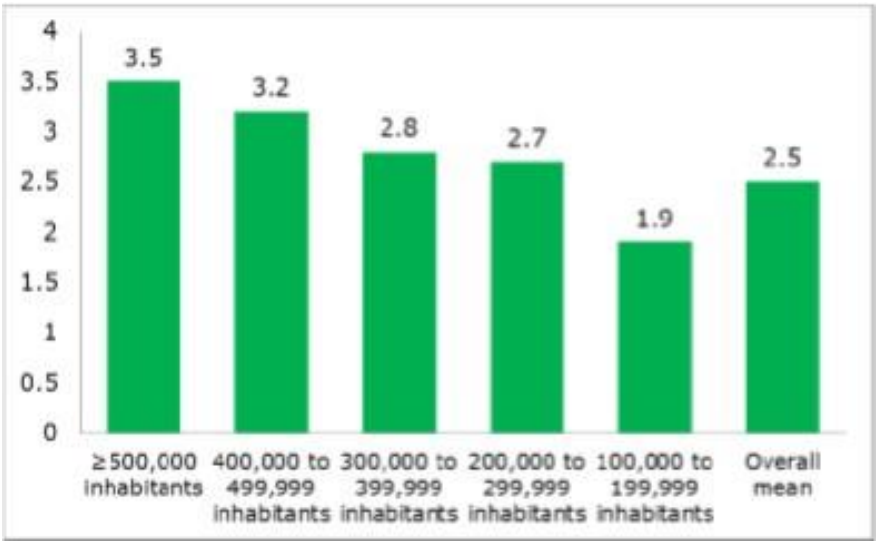


Figura 16 - Number of inhabitants in cities, according to Manville et al. (2014)

3.5. CASCAIS AS A SMART CITY

Cascais, as a smart city, has already implemented new technologies, improving citizens' daily lives who live or work there or tourists.

One good example is MOBI-Cascais (https://mobicascais.com) that consists of a transportation tool where all existing means of transportation are connected via an application.

MOBI
CASCAIS

Figura 17 - MOBI Cascais Logo

Another new initiative is FIX Cascais (http://cascais.pt/fixcascais) .With this tool, any user can report an occurence geographically inside the city.

Figura 18 - FIX Cascais Logo

Like other smart cities, Cascais produces data. This data is the blueprint for a prosperous smart city, and its' analysis constantly improves the city's performance. This data refers to the cities' residents that have the need to access said data. For that purpose, the Cascais' open data portal called Cascais Data was created, which will be explained in the following part.

Our final example of Cascais as a Smart City is the CityPoints initiative. CityPoints is a platform that enables residents and visitors in Cascais to connect their smartphones to the city's civic services and capabilities. Consumers collect points that they can then redeem for rewards from the city and local sponsors.

CityPoints is powered by a cloud-native proprietary engine called InnGage, supported by Microsoft Azure Platform as a service as:

- API Management: provide mechanisms and tools to support developer and subscriber community;
- Stream Analytics: is the processing and analysis of data records continuously rather than in batches. It is used for real-time aggregation;
- Document D.B.: a database type used to store data as documents in a format similar do JSON.
- Azure Machine Learning & Web Apps: Cloud service
- IoT Hub: back-end solution for cloud service and IoT devices

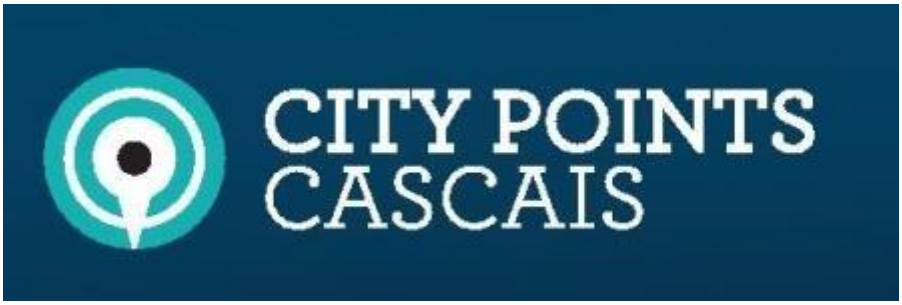


Figura 19 - City Points Cascais Logo

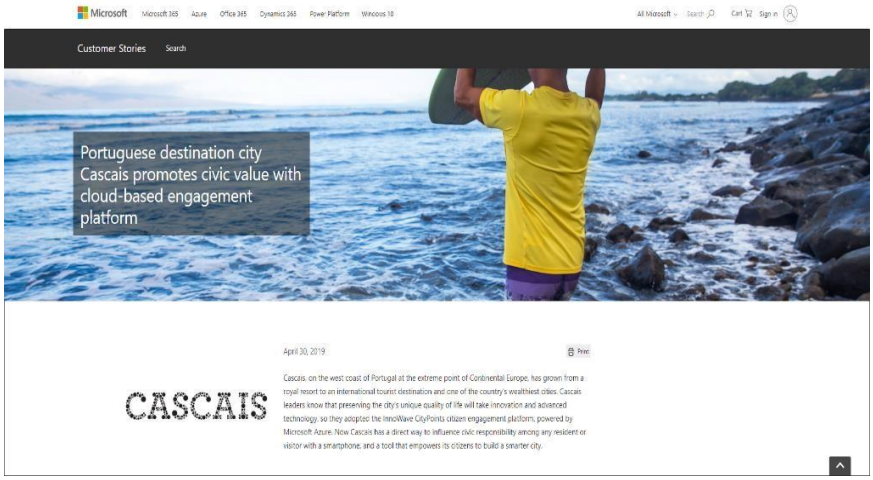


Figura 20 - Microsoft article regarding Cascais

CityPoints was a successful initiative that gained notoriety from an article published by Microsoft. CityPoints is mentioned in depth, namely its' development and functionality and its use in the everevolving Smart City of Cascais.

That being said, Cascais faces challenges as it continues to develop its' ecosystem and implement new initiatives. To combat this issue, Cascais is developing a managed services command center.

Under this plan, named Control Coordination Center (C3), data and processes from the city's disparate domains will be integrated. The first step is to define the following of each field:

- Processes;
- Organization;
- People;
- KPIs;
- Technical Services.

With all of this being said, CityPoints does not have the functionality to let users consult dashboards related to Cascais and its' many themes and functions, like green spaces, education, industry, and so on. That challenge is what led to the choice of this subject: to create dashboards that can further complement the CityPoints app, benefiting both citizens and the municipality as a whole.

3.6. Open Data

According to Ayre & Craner (2017), open data can be defined as data that we can collect and share with others, without any obstacle. One common example of open data is data collected by governments or academic sources .

Ayre & Craner (2017) state that there are two very important qualities that must be met in order for data to be considered “open”:

- Data must be “legally” open – no copyright restringements;
- Data must be “technically” open – delivered via Internet.

The figure below shows the open data charter principles that were created in 2015 by a plethora of governments and experts worldwide. They are as followed:

- **Open;**
- **Timely and Comprehensive;**
- **Accessible and Usable;**
- **Comparable and Interoperable;**
- **For Improved Governance and Citizen Engagement;**
- **For Inclusive Development and Innovation.**

Figura 21 - The Open Data Charter Principles created in 2015 by governments, civil society and experts around the world

According to Krotova et al. (2020), access to data is not evenly distributed in today's market. Because of this, the potential of open data is far from being at its' best capability. An analysis study made by Kronova et al. (2020) states that governmental data is a "public good" and that the promotion of legal certainty is an important step towards data sharing.

3.7. DATA PORTAL – CASCAIS DATA

To further complement the smart city aspect of Cascais, an open data portal named Cascais Data was created after a lengthy data collection process. It was designed to connect the city's Government and citizens when it comes to information.

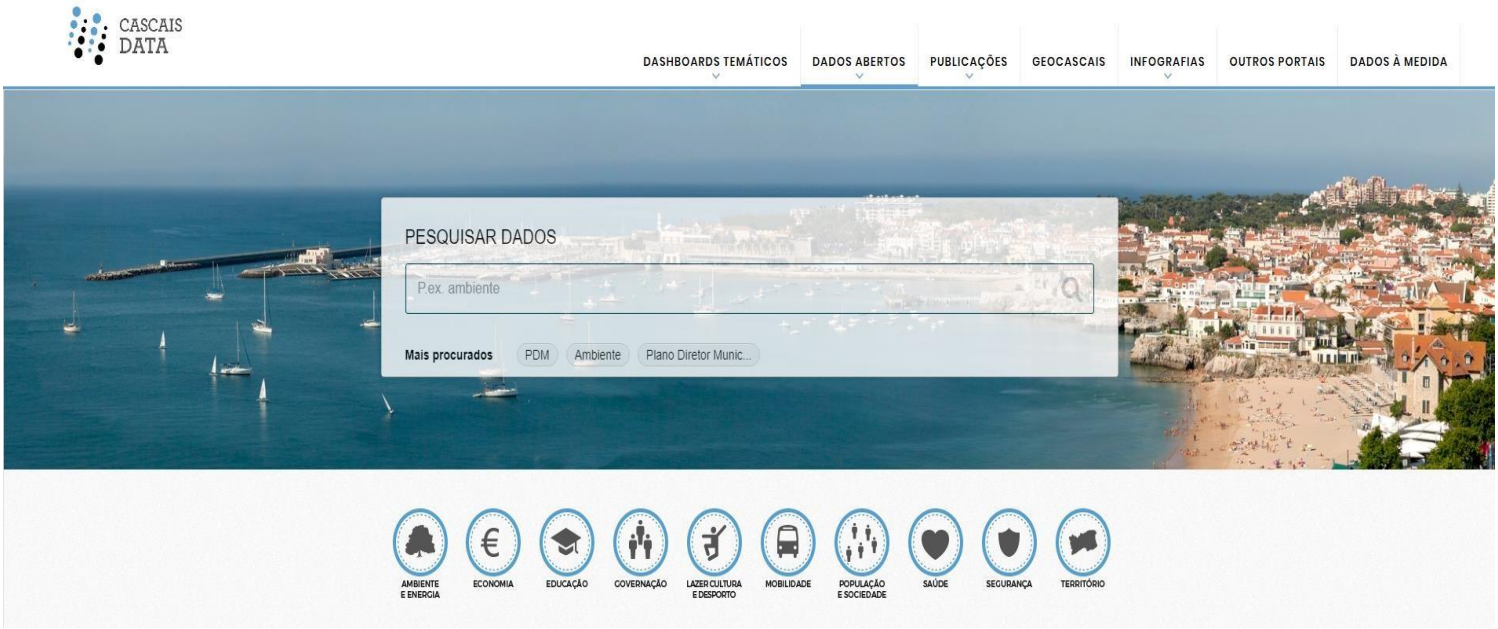


Figura 22 - Homepage of the Cascais Data Portal, taken from https://data.cascais.pt/

As seen in the figure above, Cascais Data has data on the following themes:

- Energy and Environment;
- Economy;
- Education;
- Government;
- Leisure, Culture and Sports;
- Mobility;
- Population and Society;
- Health;
- Security;
- Territory;

The Cascais Open Data portal aims to promote a culture of disseminating data and information in public management to build a reusable ecosystem and add value to data to develop innovative solutions. It is the access point for downloading data that the set of municipal entities produces and makes public, to which other entities will eventually join, sharing the information they have about the municipality of Cascais.

3.8. PORDATA

PORDATA, also known as "Base de Dados de Portugal Contemporâneo" is a data portal developed in 2009 by a group called “Francisco Manuel dos Santos”.

PORDATA embodies one of the Foundation's priorities: collecting, organizing, systematizing, and disseminating information. The Foundation's effort is to collect and organize the information available, making it as straightforward and accessible as possible.

The PORDATA data portal is free to access and without any payment charges, serving as a great benefit to Portugal, since it covers all its’ many cities and its’ many different themes.

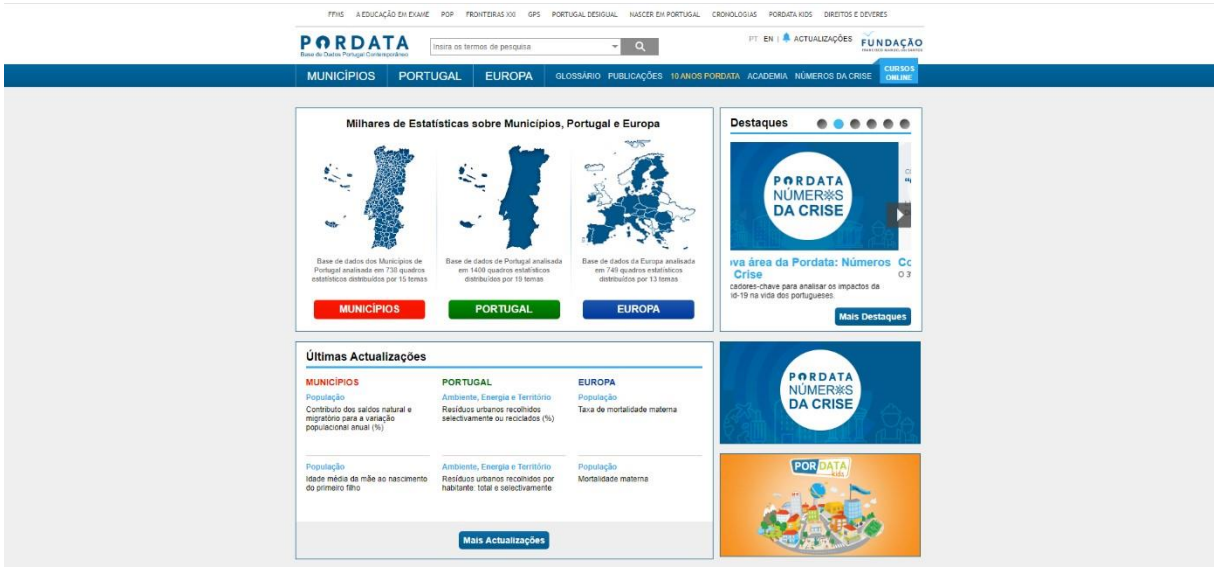


Figura 23 - Homepage of the PORDATA Portal taken from https://www.pordata.pt/

PORDATA was made public on February 23, 2010. In a similar fashion to Cascais Data and other data portals, PORDATA has data on several themes, as we can see in the following picture:

Figura 24 – All themes present in PORDATA, taken from https://www.pordata.pt/

3.9. INSTITUTO NACIONAL DE ESTATÍSTICA (INE)

INE is a data portal to produce, independently and impartially, information relevant to Portugal's inhabitant.

Statistical information must accompany the constant changes to which the Society is subject, identifying upcoming requests and making options that must be evaluated when it comes to their impact on end users. The information resulting of this process must be accessible to any user who wishes it.

Just like Cascais Data and PORDATA, INE has data on several themes such as:

- Population and Society;
- Territory and Environment;
- Economics and Finance;
- International Commerce;
- Agriculture, Forest, and Fishing;

- Industry, Energy, and Construction;
- Services;
- Innovation and Knowledge;

Figura 25 - Homepage of the Instituto Nacional de Estatística (INE) Portal taken from https://www.ine.pt/

3.10. GEOCASCAIS

Geocascais is the digital Geographic Information System (Sigweb) elected to bring together the different types of information (photographic, geographical, cadastral, urban) on Cascais, allowing an easy and fast consultation to the various data and diverse municipal cartographies it has to offer.

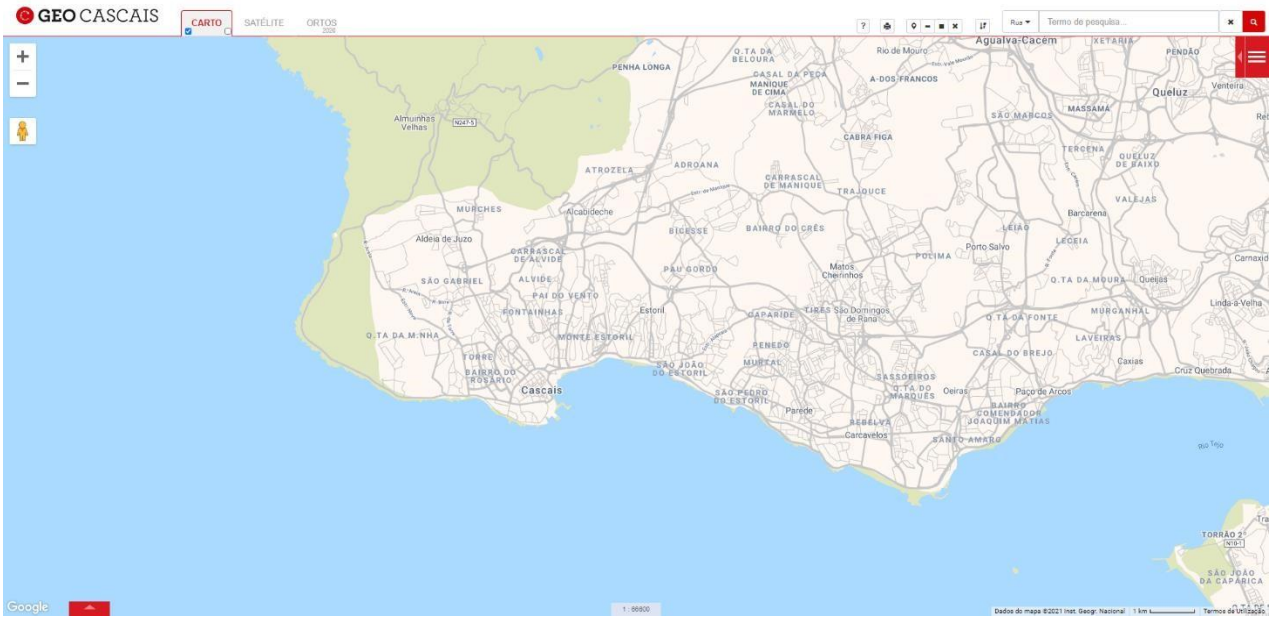


Figura 26 - Homepage of GEOCASCAIS, taken from https://geocascais.cascais.pt/

4. INDICATOR "FILTERING"

As said in the previous chapter, we must now filter all existing indicators, removing the ones that aren't present in our data or aren't suitable for our study. The following process will be followed:

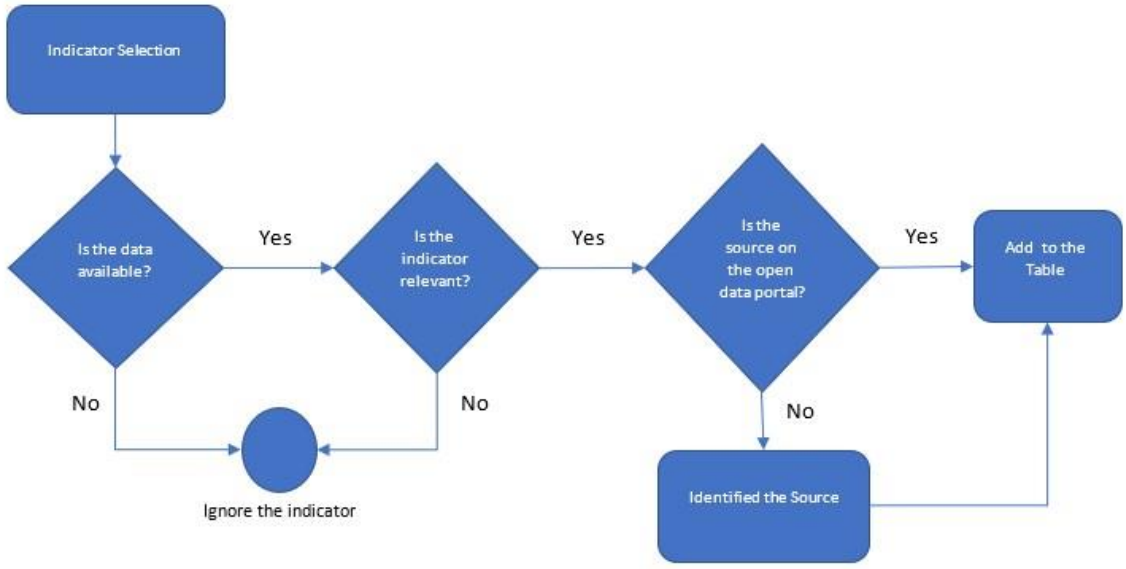


Figura 27 - Indicator Filtering Process

After the said process was completed, and taking into account the data available, we ended up with the following indicators:

- Air Quality (CO2, NO2, PM2,5);
- Green Spaces;
- Population;
- Construction & Maintenance;
- Education;
- Industry;
- Sports Facilities.

Fact Table	Source	Timeframe	Relationship
Sports Facilities	PorData, INE, GEOCASCAIS	------	Territory, Calendar
Industry	PorData, INE, GEOCASCAIS	2016-2020	Territory, Calendar
Education	PorData, INE, GEOCASCAIS	2018, 2020	Territory, Calendar
Construction & Maintenance	PorData, INE, GEOCASCAIS	2016-2020	Territory, Calendar
Population	PorData, INE, GEOCASCAIS	2011	Territory, Calendar
Air Quality	PorData, INE, GEOCASCAIS	2014-2015	Territory, Calendar

Green Spaces	PorData, INE, GEOCASCAIS	-------	Territory, Calendar

Having found our indicators, we will fit them into the proper themes in the next section.

4.1. CONCEPTUAL MODEL

Regarding the data model that will be used in this project, it is important to firstly point out the purpose of said model in our study.

In order to have a proper conceptual model, Robinson et al. (2015) state that two qualities must be met:

- **Transparency** - All stakeholders must feel at ease in using the model;
- **Comprehension** – The model must be understandable;

The following table will show the different definitions, purposes and benefits of a conceptual model, according to Robinson, Arbez, Birta, Tolk & Wagner (2015):

Conceptual model	Arbez and Birta	Robinson	Tolk	Wagner
Definition	The conceptual model is a concise and precise consolidation of all goal-relevant structural and behavioral features of the SUI presented in a predefined format.	A non-software specific description of the computer simulation model (that will be, is or has been developed), describing the objectives, inputs, outputs, content, assumptions and simplifications of the model.	Result of the processes leading from the task to the specification of the conceptualization of the ontological structure of the problem domain, comprising assumptions and constraints on all relevant modeling decisions.	A solution-independent description of a real-world problem domain, from which a platform-independent simulation design model can be derived for a given set of research questions.
Purpose	The conceptual model should enable all stake holders to discuss the SUI's behavior and it must be sufficiently comprehensive to serve as a specification for a computer program.	A simulation model cannot exist without a conceptual model. A documented conceptual model is for communication.	Capturing and communicating the conceptualization with intended as well as potentially unforeseen simulation users.	To capture a sufficiently large, and sufficiently complete, part of the real world problem domain, for which a simulation study is to be performed, in such a way that all kinds of research questions concerning this domain can be investigated.
Benefits	The conceptual model ensures that key SUI features (e.g. behavior, granularity) evolve from discussion with all stakeholders rather than from a programming bias.	A documented conceptual model is the basis for guiding all activities in simulation model development and use.	Building trust by unambiguously documenting the model – which is the foundation of the resulting simulation – which is pivotal in case of reuse or composition.	The CM can help to clarify questions about the scope and purpose of a simulation project, and it is an asset that can be re-used for making different solution designs for different research questions.

Table 5 – A summary of the perspectives of conceptual modeling, extracted from "Conceptual Model: Definition, Purpose and Benefits, written by Robinson et al. (2015)

Having established the importance of a good conceptual model, the next section will go over the data model created for our study,namely, its' dimensions and fact tables. Due to the sheer size of the model, it will be split in several images, with the relationships between them already detailed in the table in Chapter 4.

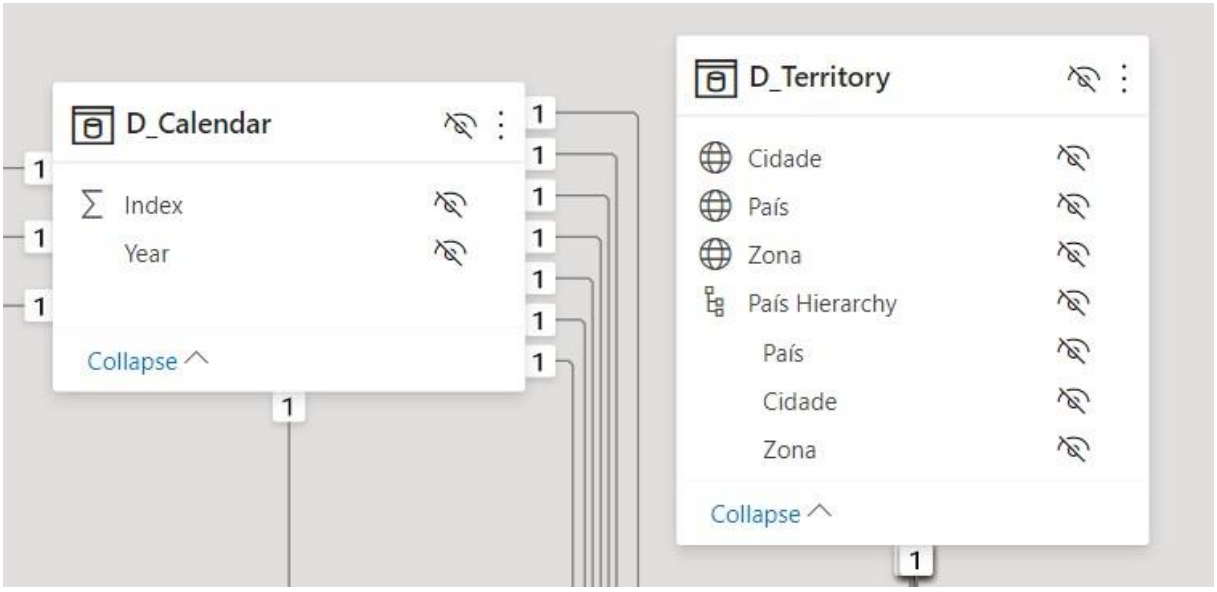


Figura 28 - Data Model Dimensions

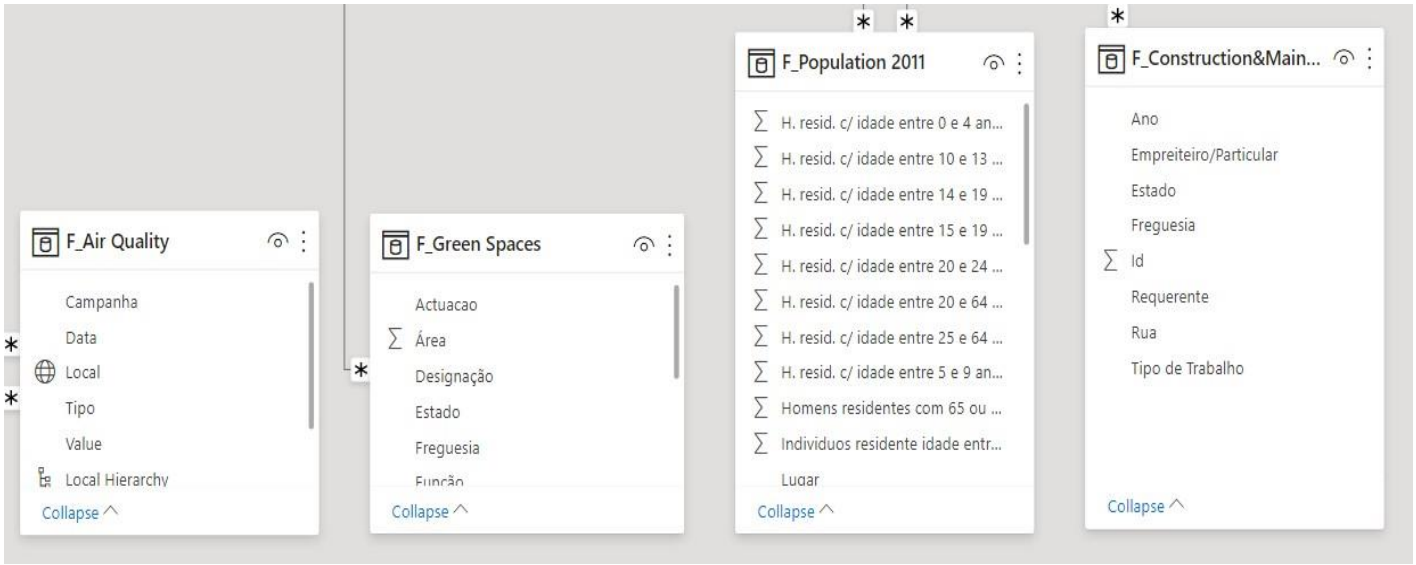


Figura 29 - Data Model Fact Tables part 1

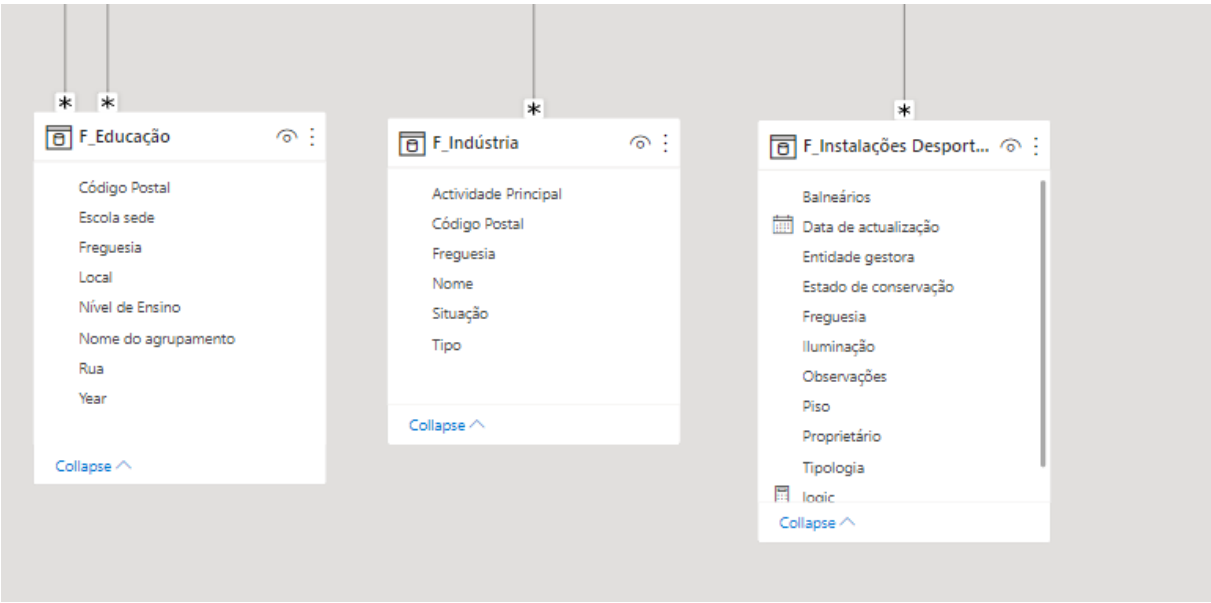


Figura 30 - Data Model Fact Tables part 2

5. CITYKEYS – CASCAIS

People
Education
Population
Sports Facilities

Planet
Air Quality
Green Spaces

Governance
Construction & Maintenance

Prosperity
Industry

Due to the lack of open data available, the Propagation theme will not be covered in our study.

6. SOFTWARE

6.1. GARTNER MAGIC QUADRANT

The Gartner Magic Quadrant is a tool created as a means to compare the many different softwares related to the same theme.

In order to achieve this, the results of its' study are placed in a graphic that is divided in 4 pillars, in order to easily understand comprehend what are the leading tools in a specific year, as seen in the following figure:

Figura 30 - Gartner Magic Quadrant, taken from https://www.gartner.com/en/research/methodologies/magic-quadrants-research

The Gartner Magic Quadrant presents itself as an ideal way to understand which software is best applicable for a specfic business need.

6.1.1. SOFTWARE COMPARISON

Figura 31 - Gartner Magic Quadrants 2017 - 2020

Figura 32 - Gartner Magic Quadrant 2021

Figura 33 - Power BI vs Tableau vs QlikView, according to SelectHub

Based on the table and the figures above, we can conclude that Power Bi is the preferred software for our analysis and will henceforth be the program used in our study. It is noteworthy to point out that Tableau holds an advantage over Power BI when it comes to dashboards and data visualization. However, the many positives of Power BI, mainly regarding data connectivity and reporting, make it the overall best choice, regardless.

6.2. TABLEAU

To put it simply, Tableau is a software tool used in BI, assisting in the simplification of incomprehensible data into easy to understand information in the form of visualizations.

Unlike other software tools, Tableau is noteworthy in the sense that it doesn't require any prior technical knowledge to use it. Because of this, it has gained notoriety in many different divisions such as business, research, and industries.

In the following table, we can see the comparison between Tableau and Excel, a more well known tool:

Parameters	Excel	Tableau
Purpose	Spreadsheet application used for manipulating the data.	Perfect visualization tool used for analysis.
Usage	Most suitable for statistical analysis of structured data.	Most suitable for quick and easy representation of big data which helps in resolving the big data issues.
Performance	Moderate speed with no option to quicken.	Moderate speed with options to optimize and enhance the progress of an operation.
Security	The inbuilt security feature is weak when compared to Tableau. The security update needs to be installed on a regular basis.	Extensive options to secure data without scripting. Security features like row level security and permission are inbuilt.
User Interface	To utilize excel to full potential, macro and visual basic scripting knowledge is required	The tool can be used without any coding knowledge.
Business need	Best for preparing on-off reports with small data	Best while working with big data.
Products	Bundled with MS Office tools	Comes with different versions such as the Tableau server, cloud, and desktop.
Integration	Excel integrates with around 60 applications	Tableaus integrated with over 250 applications
Real time data exploration	When you are working in excel, you need have an idea of where your data takes you to get to know the insights	In Tableaus, you are free to explore data without even knowing the answer that you want. With the in-built features like data blending and drill-down, you will be able to determine the variations and data patterns.
Easy Visualizations	When working in excel, we first manipulate the data that is present and then the visualization such as the different charts, graphs are created manually. To make the visualizations easily understandable, you should understand the features of excel well.	Whereas in Tableau, the data is visualized from the beginning.

Figura 34 – Excel vs Tableau comparison table, taken from ChromeInfoTech.net

6.3. QLIKVIEW

QlikView is another Business Intelligence data visualization tool. It is a BI tool that presents data in a rich yet easily understood manner.

The principal sections of Qlikview are as followed:

- Desktop;
- Server;
- Publisher.

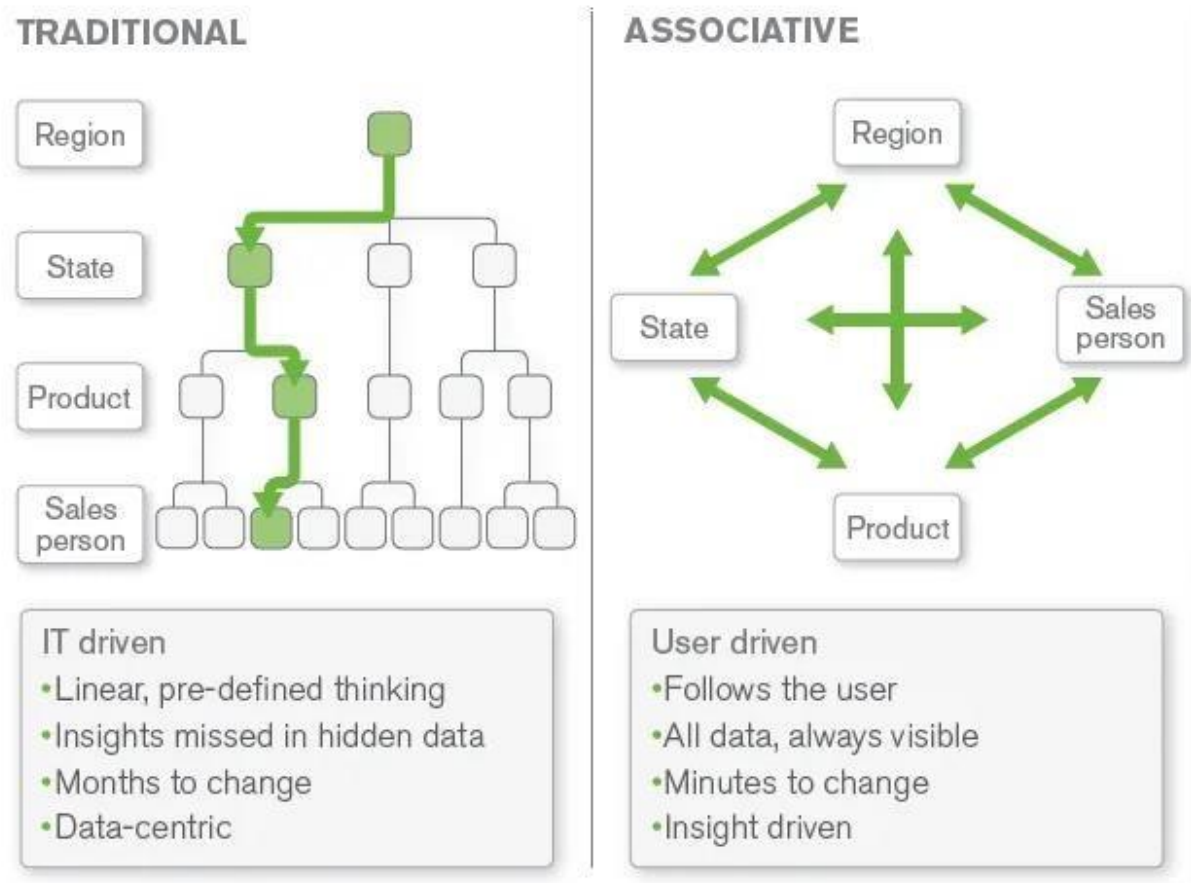


Figura 35 - QlikView Architecture, according to their own website

6.4. POWER BI

The software that we will be using to build our dashboard is Power BI. It provides user friendly data visualizations that are informative as well as interactive.

For this project in particular, the tool that will be used is Power BI Desktop, mainly its' dashboard functionality.

Figura 36 - Power BI Logo

Power BI has many key features, some of them being:

- **Hybrid development support**;
- **Power Query**;
- **Use of schemas**;
- **Customizable;**
- **Dashboards** ;
- **Model view**.

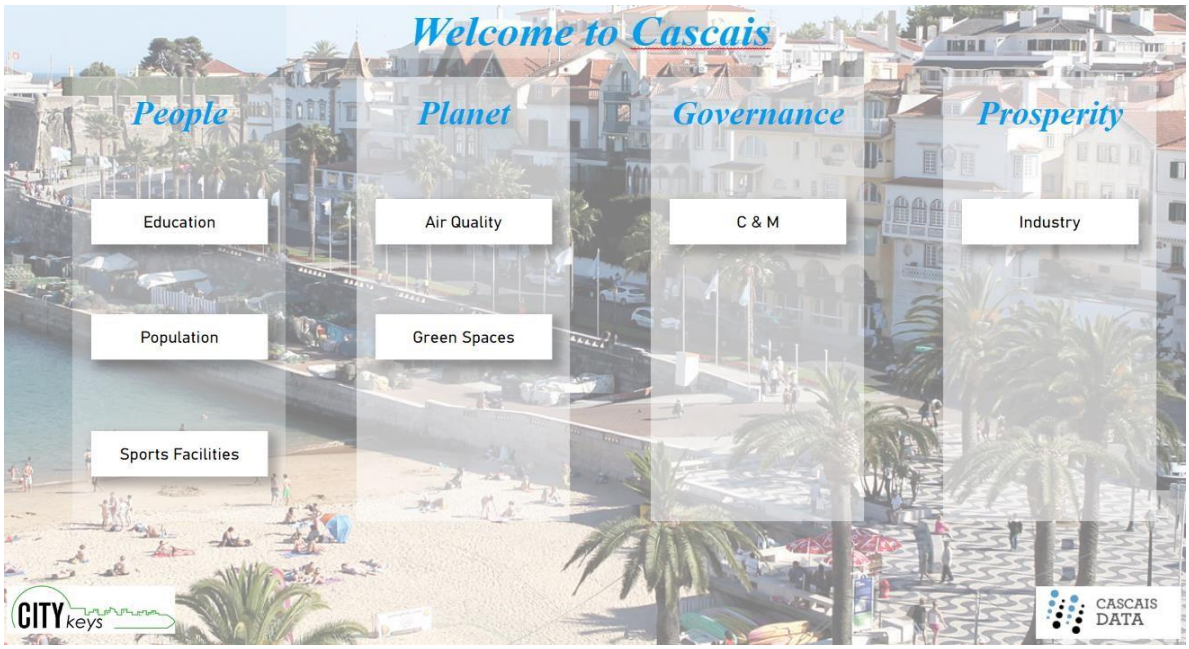
Aswell as its' varied features, Power BI also holds many advantages, such as:

- Low cost in order to properly view a dashboard;
- Very easy to learn if the user is already familiar with similar tools;
- As Microsoft powers Power BI, there is always help at hand for learning;
- Data across all systems can easily be shared (Windows, Android, and iOS).

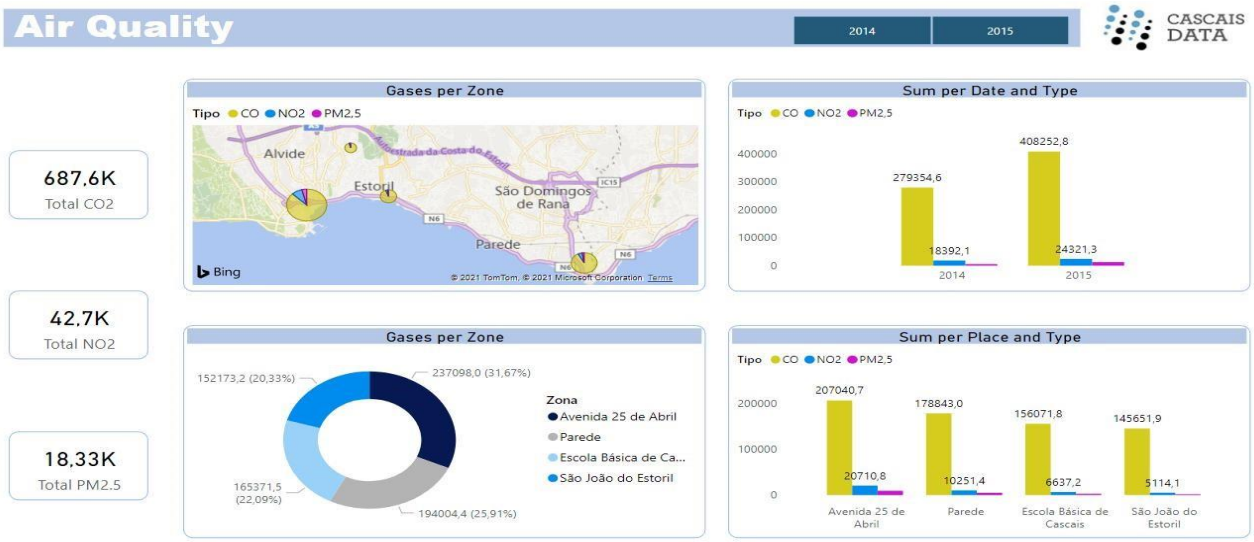
To create great data visualizations, Power BI connects to data sources and builds reports. Although business analysts and data scientists mainly use Power BI, many people from many backgrounds within a business can use Power BI due to its user-friendly nature .

7. DASHBOARD MOCKUPS

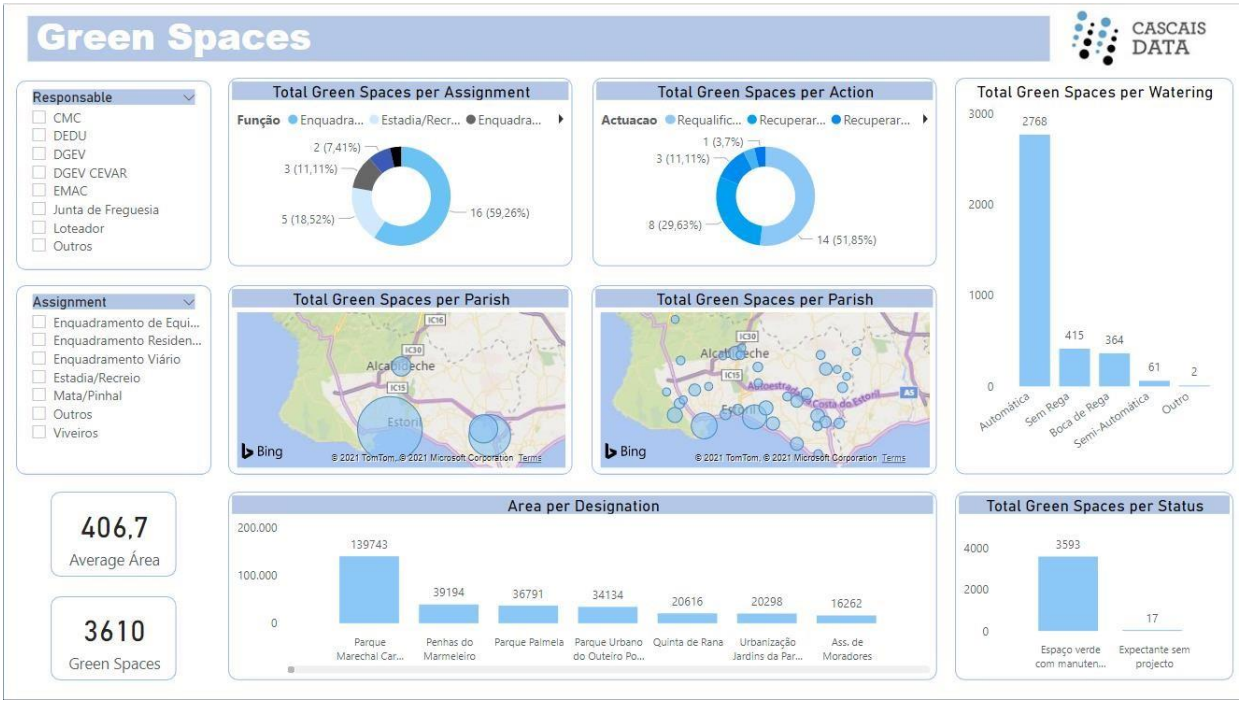
7.1. MAIN MENU



7.2. AIR QUALITY

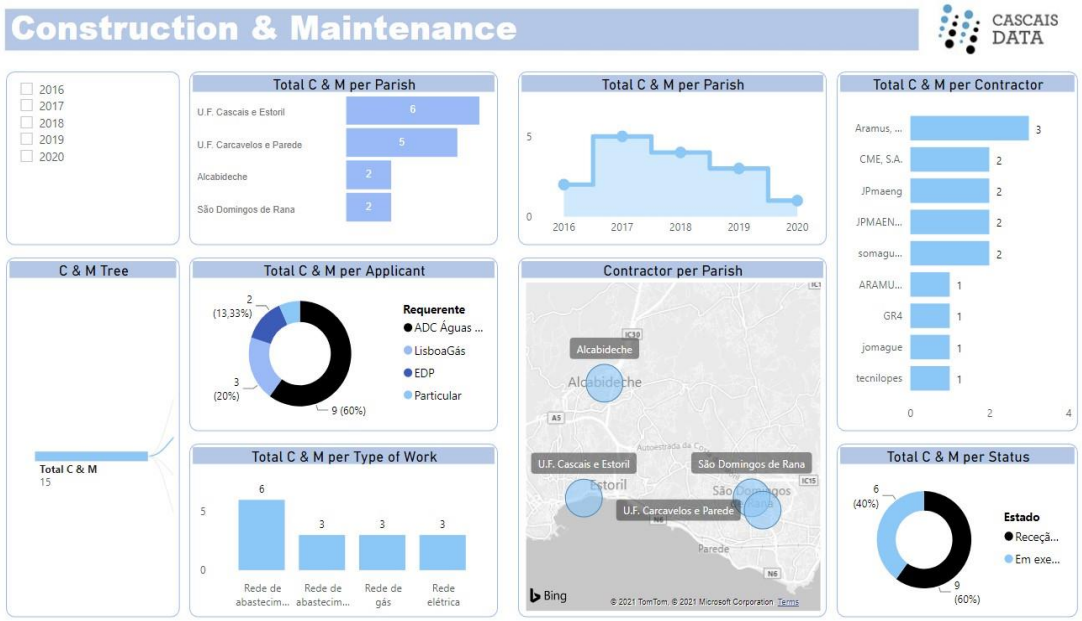


7.3. GREEN SPACES

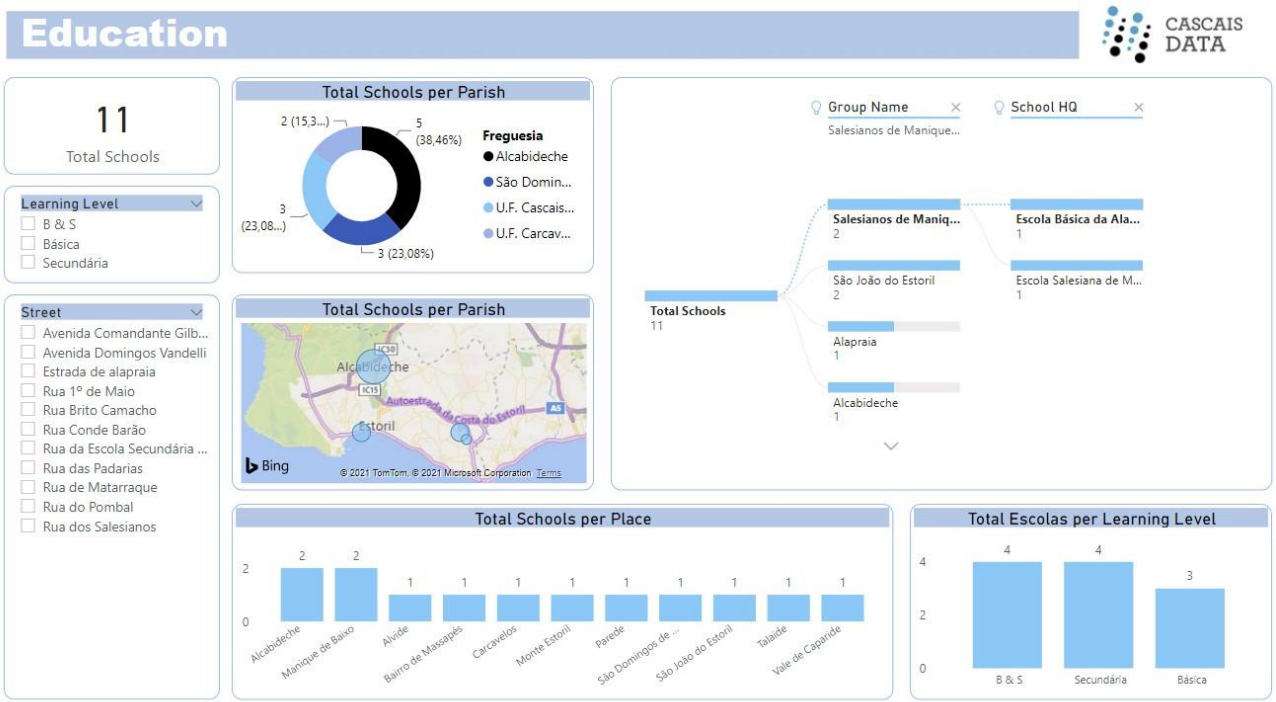


7.4. POPULATION

7.5. CONSTRUCTION & MAINTENANCE

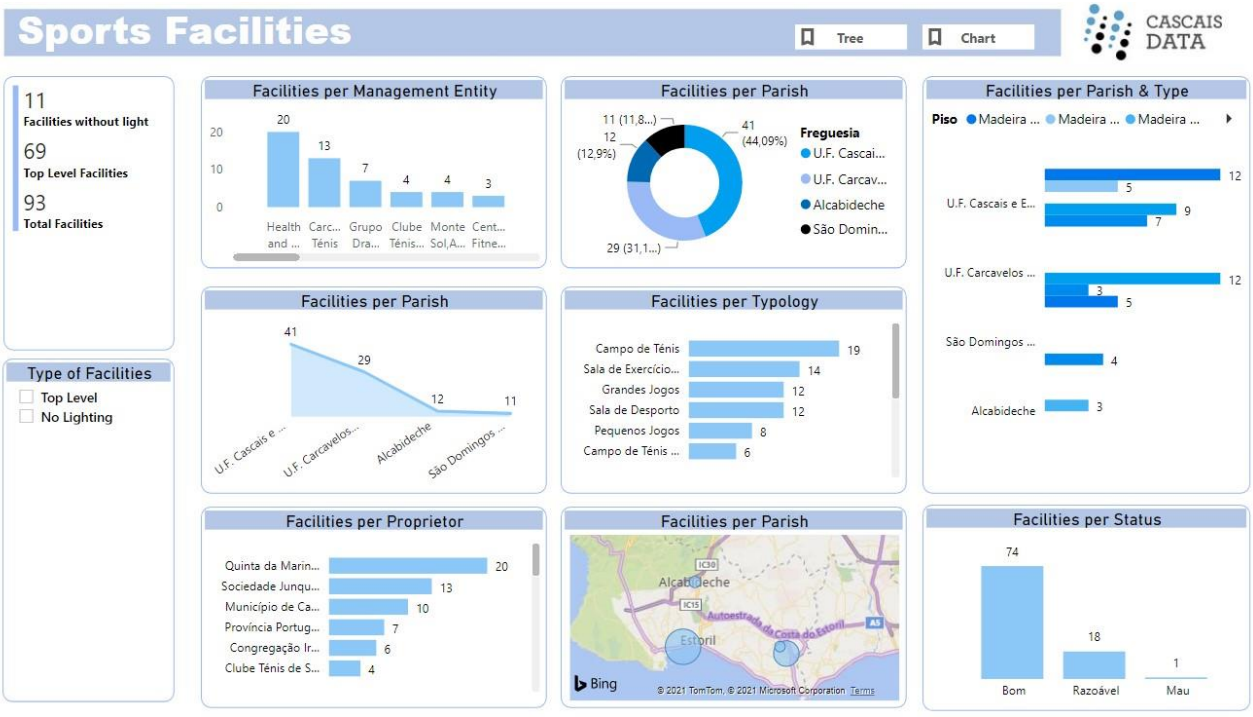


7.6. EDUCATION



7.7. INDUSTRY

7.8. SPORTS FACILITIES



8. ANALYSIS

We can now begin our analysis and results-gathering process by our study goals and business needs after creating our mockups.

8.1. AIR QUALITY

Looking at the map, we can see that the focal points are the center of Cascais, the casino area of Estoril, and Parede, which are the three places with the most infrastructures, hence, the places that have a bigger output of gases. CO2 is by a large margin the most produced gas, mainly due to the absence of trees to absorb carbon dioxide around the main areas, as well as an increased amount of vehicle pollution in this area.

8.2. GREEN SPACES

Taking a look at Green Spaces, the biggest one happens to be Parque Marechal Carmona, easily the most popular park in Cascais. Of the 3610 total green spaces, 1426 are split between Cascais and Estoril. Also, 2768 parks have an automatic irrigation system implemented which is a very healthy number. Thankfully, only 17 parks are on standby when it comes to their maintenance status, with all other parks benefiting from steady maintenance.

If we go even deeper, the main parishes with the greenest spaces are the center of Cascais and São João do Estoril. When it comes to the latter, this can be explained by the large park that runs from the Casino Estoril to the train station, a very popular landmark in the area.

8.3. POPULATION

Moving on to population, one quick look at the graph tells us that there are more women (green) than men (purple) in pretty much every area in and around Cascais. Furthermore, 40% of men are in the 25-64 age group versus the women's 36%, although women have 13% in the 65+ age group which can be attributed to the overall better longevity of the female gender. That being said, in both genders the biggest age group is the one from 20-64 years old.

8.4. CONSTRUCTION & MAINTENANCE

When it comes to Construction & Maintenance, the places with the most work done are naturally the ones filled with the most infrastructures which correspond to the main areas in Cascais, such as Cascais, Estoril, Carcavelos, and Parede. We can also see that the most frequent maintenance job is for Water Supplying. Finally, Aramus is the most sought out contractor in Cascais.

8.5. EDUCATION

Taking a look at Education, there are eleven schools in total, with three belonging to the parish of Cascais. Alcabideche is the leading parish with five schools, with most schools providing both basic and secondary learning levels. There is a direct correlation between the quality of the school and the development/wealth of its' location (the richer the area the better the school).

8.6. INDUSTRY

Looking at the Industry map, we can see that São Domingos de Rana is the area with the most industry facilities by a landslide, with 217. As expected, the center of Cascais and the areas adjacent to it do not have any facilities due to it being a more residential and wealthy area. São Domingos de Rana and Alcadebiche, being the largest and less populated areas, host the biggest number of facilities.

8.7. SPORTS FACILITIES

When it comes to sports facilities, there is a pattern between the areas with the most population and the quality and quantity of available locations. In this aspect, Cascais holds the most courts for the practice of sports with 41, especially tennis and padel, both being the most popular sports to play, alongside football. Thankfully, in the area of Cascais, the majority of sports facilities are in good condition with a sole exception being in bad condition, namely, Grupo Desportivo do Zambujeiro in Alcabideche.

Of the total 93 facilities, 69 of them have both lighting and locker rooms, being considered as "Top Facilities" in our study. 11 facilities have no lighting, with 5 of them located in Carcavelos & Parede.

9. LIMITATIONS

There were many limitations developing this project, such as:

- Very little open data available (the municipality has the data but does not share it with the users);
- The lack of quality in data was severely noticed in some themes and service providers of the municipality did not address the project's needs;
- The data available does not share the same temporal intervals and features in all the departments of the municipality which makes the comparison process difficult;
- The absence of data up-to-date on Cascais.

10. CONCLUSION

The dashboards constructed were made as an attempt to translate the data related to the municipality of Cascais into insightful information.

Thanks to the literature review of the project, we can conclude that there is evidence of a growing trend towards the existence of smart cities and open data portals. These keywords are increasingly a constant topic in the management of cities.

Some Smart Cities, in this case Cascais, are limited to the release of raw data, without creating frameworks that translate this data into information easily interpreted by any stakeholder of the city, which is why this topic was chosen as the subject of the thesis.

The created mockups are easily applicable and understandable to any organization that also uses the Microsoft Power BI tool and an advantage to ensure uniformity throughout the organization. It also can help beginner builders of dashboards who do not have experience in construction and lack of design notion.

This project was helped by processes easily adapted to any city and shows how the monitoring of data can be useful in the daily life of citizens. It is known that dashboards are a big benefit to the monitoring of the data about the municipality of Cascais since they can effectively summarize, show accurately, and select relevant information of interest in regards to many different themes.

11. BIBLIOGRAPHY

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12. ANEXOS

1.1 People

1.1.2 Safety

Indicator title	Indicator unit	Definition	Source
Traffic accidents	#/100.000	Number of transportation fatalities per 100.000 population	Civitas; Rotterdam SCP; European Green Capital Award study; 2Decide; CASBEE_City_2012; UNECE; ,GCIF; COMIND; URBES
Crime rate	#/100.000	Number of violence, annoyances and crimes per 100.000 population	Rotterdam SCP; Smart city Wheel; European Smart Cities v1.0 (2007); SCI; City Protocol; GCIF
Cybersecurity	Likert	The level of cybersecurity of the cities' systems	
Data privacy	Likert	The level of data protection by the city	

1.1.3 Access to (other)services

Indicator title	Indicator unit	Definition	Source
Access to public transport	% of people	Share of population with access to a public transport stop within 500m	Rotterdam SCP; Covenant of mayors; OECD; City Protocol; GCIF; 2000-Watt;
Access to vehicle sharing solutions for city travel	#/100.000	Number of vehicles available for sharing per 100.000 inhabitants	LEED; DGNB
Length of bike route network	% in km	% of bicycle paths and lanes in relation to the length of streets (excluding motorways)	FIN Indicators; Transform; OECD; UNECE; Covenant of Mayors; European Green Capital Award study; City Protocol; URBES; ISO 37120
Access to public amenities	% of people	Share of population with access to at least one type of public amenity within 500m	Smart city Profiles; RFSC; FIN indicators; Eurbanlab; 2000Watt; SCI; Rotterdam SCP; City Protocol
Access to commercial amenities	% of people	Share of population with access to at least six types of commercial amenities providing goods for daily use within 500m	Eurbanlab ,OECD, Rotterdam SCP; City Protocol
Access to high speed internet	#/100	Fixed (wired)-broadband subscriptions per 100 inhabitants	ISO 37120; RFSC; Rotterdam SCP; Transform; UNECE; ITU; Green Digital Charter; European Green Capital Award study; City Protocol; GCIF; URBES; Smart city Wheel; Triple Helix Model; European Smart Cities v1.0 (2007);
Access to public free WiFi	% of m2	Public space Wi-Fi coverage	City Protocol
Flexibility in delivery services	Likert	The extent to which there is flexibility in delivery services	

1.1.4 Education

Indicator title	Indicator unit	Definition	Source
Access to educational resources	Likert	The extent to which the city provides easy access (either physically or digitally) to a wide coverage of educational resources	Adapted from project definition
Environmental education	% of schools	The percentage of schools with environmental education programs	SCI
Digital literacy	% of people	Percentage of target group reached	

1.1.5 Diversity and social cohesion

No indicators identified at city level.

1.1.6 Quality of housing and the built environment

Indicator title	Indicator unit	Definition	Source
Diversity of housing	Simpson Diversity Index/Social housing	Simpson Diversity Index of total housing stock in the project area OR Percentage of social dwellings as share of total housing stock in the project area	LEED; UNECE; City Protocol; Eurbanlab; SCI
Preservation of cultural heritage	Likert	The extent to which preservation of cultural heritage of the city is considered in urban planning	Eurbanlab; CASBEE_Urban development_2014
Ground floor usage	% of m2	Percentage of ground floor surface of buildings that is used for commercial or public purposes as percentage of total ground floor surface	
Public outdoor recreation space	m2/cap	Square meters of public outdoor recreation space per capita	OECD; Rotterdam SCP; City Protocol

Green space	hectares/100.000	Green area (hectares) per 100.000 population	UNECE; ClimateCon; OECD; SCI; European Green Capital Award study; City Protocol; GCIF; URBES; Rotterdam SCP

1.2 Planet

1.2.1 Energy & mitigation

Indicator title	Indicator unit	Definition	Source
Energy consumption/demand			
Annual final energy consumption	MWh/cap/yr	Annual final energy consumption for all uses and forms of energy	Eurbanlab; Transform
Renewable energy production			
Renewable energy generated within the city	% of MWh	The percentage of total energy derived from renewable sources, as a share of the city's total energy consumption	Eurbanlab; Transform; OECD; UNECE; READY
CO2 –emissions			
CO2 emissions	t CO2/cap/yr	CO2 emissions in tonnes per capita per year	ISO 37120; Smart city Wheel; SCI; FIN indicators; DESIRE; RFSC; UNECE; European Green Capital Award study; City Protocol; GCIF
Local freight transport fuel mix	% in kms	The ratio of renewable fuels in the local freight transport fuel mix.	2DECIDE CIVITAS

1.2.2 Materials, water and land

Indicator title	Indicator unit	Definition	Source
Materials			
Domestic material consumption	t/cap/year	The total amount of material directly used in the city per capita	
Water consumption	liters/cap/year	Total water consumption per capita per day	Siemens Green City Index; FIN Indicators; European Green Capital Award study; UNECE; OECD; ClimateCon; Rotterdam SCP; City protocol; GCIF; COMIND
Grey and rain water use	% of houses	Percentage of houses equipped to reuse grey and rain water	OECD
Water Exploitation Index	% of m3	Annual total water abstraction as a percentage of available long-term freshwater resources in the geographically relevant area (basin) from which the city gets its water	DESIRE
Water losses	% of m3	Percentage of water loss of the total water consumption	Siemens Green City Index; UNECE; FIN Indicators; City Protocol; GCIF; URBES
Land			
Population density	#/km2	Number of people per km2	FIN Indicators
Local food production	% of tonnes	Share of food consumption produced within a radius of 100 km	
Brownfield use	% of km2	Share of brownfield area that has been redeveloped in the past period as percentage of total brownfield area	

1.2.3 Climate resilience

Indicator title	Indicator unit	Definition	Source
Climate resilience strategy	Likert scale	The extent to which the city has developed and implemented a climate resilient strategy	Eurbanlab
Urban Heat Island	°C UHImax	Maximum difference in air temperature within the city compared to the countryside during the summer months	

1.2.4 Pollution & waste

Indicator title	Indicator unit	Definition	Source
Air quality			
Nitrogen oxide emissions (NOx)	g/cap	Annual nitrogen oxide emissions (NO and NO2) per capita	Siemens Green City Index; European Green Capital Award study
Fine particulate matter emissions (PM2.5)	g/cap	Annual particulate matter emissions (PM 2,5) per capita	Siemens Green City Index; European Smart Cities v1.0 (2007); European Green Capital Award study; Civitas
Air quality index	Index	Annual concentration of relevant air pollutants	RFSC; FIN Indicators; Rotterdam SCP; OECD; COMIND
Miscellaneous			
Noise pollution	% of people	Share of the population affected by noise >55 dB(a) at night time	ISO 37120; FIN Indicators; Rotterdam SCP; OECD; ClimateCon; European Green Capital Award study; City Protocol; URBES
Waste			
Municipal solid waste	t/cap/yr	The amount of municipal solid waste generated per capita annually	Siemens Green City Index; Smart city Profiles; Rotterdam SCP; Transform; Desire; OECD; ClimateCon; SCI; European Green Capital Award study; City Protocol
Recycling rate	% of tonnes	Percentage of city's solid waste that is recycled	Siemens Green City Index; Smart city Profiles; Rotterdam SCP; Desire; OECD; ClimateCon; CASBEE_City_2012; SCI; City Protocol; GCIF; 2000-Watt

1.3 Prosperity

1.3.1 Employment

Indicator title	Indicator unit	Definition	Source
Uneployment rate	% of people	Percentage of the labour force unemployed	ISO 37120, ClimateCon; SCI; European Green Capital Award study; City Protocol; UN HABITAT CPI; GCIF; Triple Helix Model; SCI; European Green Capital Award study; COMIND; RFSC; UNECE
Youth unemployment rate	% of people	Percentage of youth labour force unemployed	ISO 37120; European Green Capital Award study; City Protocol

1.3.2 Equity

Indicator title	Indicator unit	Definition	Source
Fuel poverty	% of households	The percentage of households unable to afford the most basic levels of energy	Eurbanlab; Transform
Affordability of housing	% of people	% of population living in affordable housing	Eurbanlab; UNECE; SCI

1.3.3 Green economy

Indicator title	Indicator unit	Definition	Source
Share of certified companies	% of companies	Share of companies based in the city holding an ISO 14001 certificate	
Share of Green Public Procurement	% in €	Percentage annual procurement using environmental criteria as share of total annual procurement of the city administration	FIN Indicators
Green jobs	% of jobs	Share of jobs related to environmental service activities that contribute substantially to preserving or restoring environmental quality	Green Digital Charter; SCI; Transform
Freight movement	# of movements	Freight movement is defined as the number of freight vehicles moving into an area (e.g. the city)	2DECIDE CIVITAS

1.3.4 Economic performance

Indicator title	Indicator unit	Definition	Source
Gross Domestic Product	€/cap	City's gross domestic product per capita	Triple Helix Model; Green Digital Charter; ClimateCon; City Protocol; UN Habitat CPI; GCIF; READY; UNECE
New business registered	#/100.000	Number of new businesses per 100,000 population	Triple Helix Model; European Green Capital Award study; City Protocol
Median disposable Income	€/household	Median disposable annual household income	ClimateCon; European Green Capital Award study; GCIF; COMIND; Triple Helix Model

1.3.5 Innovation

Indicator title	Indicator unit	Definition	Source
Creative industry	% of people	Share of people working in creative industries	Triple Helix Model; European Green Capital Award study; Smart city Wheel
Innovation hubs in the city	#/100.000	# of innovation hubs in the city, whether private or public, per 100.000 inhabitants	
Accessibility of open data sets	# stars	The extent to which the open city data are easy to use	City Protocol
Research intensity	% in euros	R&D expenditure as percentage of city's GDP	Triple Helix Model; ITU; UNECE; Smart city Wheel; European Smart Cities v1.0 (2007)
Open data	#/100.000	# of open government datasets per 100.000 inhabitants	

1.3.6 Attractiveness & competitiveness

Indicator title	Indicator unit	Definition	Source
Congestion	% in hours	Increase in overall travel times when compared to free flow situation (uncongested situation)	IDEAS; European Green Capital Award study; City protocol; 2Decide
Public transport use	#/cap/year	Annual number of public transport trips per capita	City Protocol; ISO 37120; GCIF
Net migration	#/1000	Rate of population change due to migration per 1000	CASBEE_City_2012; European Green Capital
Population Dependency Ratio	#/100	Number of economically dependent persons (net consumers) per 100 economically active persons (net producers)	GCIF
International Events Hold	#/100.000	The number of international events per 100.000 inhabitants	Smart city Wheel
Tourism intensity	#/100.000	Number of tourist nights per year per 100.000 inhabitants	UNECE; European Green Capital Award study; Triple Helix Model

1.4 Governance

1.4.1 Organisation

Indicator title	Indicator unit	Definition	Source
Cross-departmental integration	Likert	The extent to which administrative departments contribute to "smart city" initiatives and management	Transform
Establishment within the administration	Likert	The extent to which the smart city strategy has been assigned to one department/director and staff resources have been allocated	Smart city Profiles
Monitoring and evaluation	Likert	The extent to which the progress towards a smart city and compliance with requirements is being monitored and reported	RFSC
Availability of government data	Likert	The extent to which government information is published	ITU

1.4.2 Community involvement

Indicator title	Indicator unit	Definition	Source
Citizen participation	% of projects	The number of projects in which citizens actively participated as a percentage of the total projects executed	Transform
Open public participation	#/100.000	Number of public participation processes per 100.000 per year	City Protocol
Voter participation	% of people	% of people that voted in the last municipal election as share of total population eligible to vote	ISO 37120; European Smart Cities v1.0 (2007); UNECE; European Green Capital Award study; City protocol; GCIF; COMIND

1.4.3 Multi-level governance

Indicator title	Indicator unit	Definition	Source
Strategies and policies			
Smart city policy	Likert	The extent to which the city has a supportive smart city policy	
Budget			
Expenditures by the municipality for a transition towards a smart city	€/capita	Annual expenditures by the municipality for a transition towards a smart city	Smart city Profiles
Multilevel			
Multilevel government	Likert	The extent to which the city cooperates with other authorities from different levels	RFSC