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METHODOLOGIES FOR PROJECTING AND IMPLEMENTING A SMART WATER CITY

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TABLE OF CONTENTS

INTRODUCTION

ABSTRACT

"Our problems are man-made, so they can be solved by man." J. Fitzgerald Kennedy's phrase reflects the current scenario, characterised by the phenomenon of climate change, largely caused by human activity since the first Industrial Revolution, which is beginning to show the damage it causes, such as the anomalous temperatures and severe droughts recorded in Italy in the summer of 2022. Among the many dimensions of nature affected by these changes, there is also water: a study coordinated by the Institute of Marine Sciences of the Superior Council for Scientific Research (Icm-Csic) in Barcelona shows how global warming is accelerating the water cycle: a phenomenon that could irreversibly alter the equilibrium of the entire Earth ecosystem, causing more violent storms and causing ice to melt rapidly. One of the effects of these changes is that the space mainly occupied by humans, i.e. the city, is creating challenges for public decision-makers in terms of both urban water management and the provision of urban water and sanitation services. Indeed, the growth of cities, climate change and increasing urbanisation rates have had an impact on the natural water cycle and cities, today, are at the centre of the problem. Furthermore, they today can be subject to environmental disasters such as floods and tropical storms, which pose a serious threat to the lives and well-being of thousands of people, as well as a problem for the environment. Among the numerous issues, the expansion of urban areas is creating difficulties in providing adequate drinking water and sanitation services in many areas of the world, as well as making it difficult to manage the expansion and renewal of water networks in extended urban areas. In this context, one possible solution is represented by the Smart Water Cities, i.e. smart cities that pay special attention to citizens' water consumption levels and, in general, to the management and maintenance of the city's water network and its related hydric resources. The paper thus aims to present the Smart Water City concept and the methods through which to design, implement and evaluate a smart city project. In particular, the first chapter will present the fundamental concepts, which will form the theoretical substrate on which the paper is based. In fact, the definition of the smart city concept, its main characteristics and the benefits it can bring to a city project will be presented. In the last part, the public and private financing methods through which these

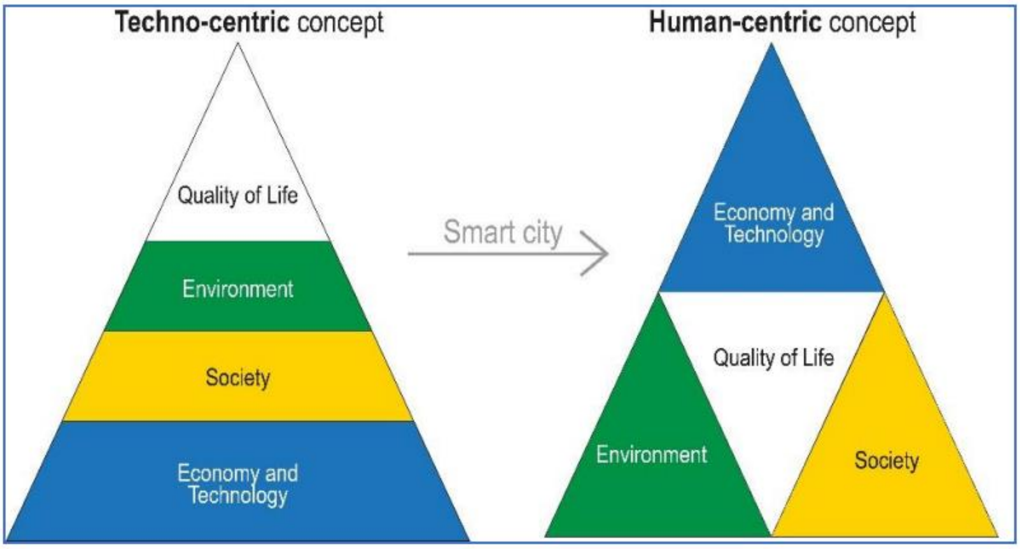
projects are made possible will also be presented. In the second chapter, a definition of the Smart Water City concept will be provided and the main benefits that such solutions bring will be presented. It will also analyse what the city's water network looks like, from the individual building to the entire city water system. In the final part of the chapter, the problems and obstacles to the deployment of such urban projects will first be analysed, concluding with the definition of a roadmap to enable the transition from a Smart City to a Smart Water City. In the third chapter, the main indexes and tools through which a Smart Water City can be managed will be listed. In particular, it will be presented an useful tool that can be used to support the urban transition’ process: the Water Sensitive City Index. In the fourth chapter, multiple use cases from Smart Water City projects promoted and developed in cities around the world will be considered. The aim of this chapter is to show how some realities are already putting in place practices to transition toward a Smart Water City and what benefits they have brought to the urban agglomeration. The last chapter will contain a brief discussion of the work and recommendations and advice for possible future related research. Finally, the conclusions that can be drawn in the light of this work will be presented.

CHAPTER 1

1.1. Definition of the basic concepts and evolution of the concept

The first theoretical cornerstone that will set the point of departure of this research is represented by the definition of what a Smart City is. Despite the theme has been addressed and debated since a long time, still it persists a lot of confusion around it. According to the main authors who wrote on the subject, the first idea of smart city was born during the '90s. In particular, according to Cocchia[1], the event that set the base for a worldwide diffusion of this idea was the 1997 Kyoto Protocol. In this historical event, almost all the world countries reunited to sign this Protocol, which acted as a guarantee that the signatory state would have put in place all useful measures to reduce the pollution produced by its nation. It is exactly in this scenario that the first "smart projects" were created, in order to satisfy the Protocol's requirements, through the use of the information and communication technologies.

Then, until the first decade of the new millennium, the main focus of the literature was revolving around the conceptual aspects of the smart cities, in particular, they mainly focused on the technology. According to this view, the technical capital possessed by a city would have formed the base upon which build the other dimensions of a smart city, such as environment and quality of life. In general, the term of "smart city" was always accompanied by technology-related features. Indeed, terms such as ICT and IOT have proven their importance as being the main actors for the planning, development and implementation of an urban transformation process. From 2012 onward, a new branch of literature begins to develop, trying to develop an holistic and integrated view of the urban area, very far from the traditional 'silos' approach, in which the various elements that make up the urban scenario are seen as watertight and separated from each other . According to this "human-centric" approach, each relevant dimension of the city has the same importance as the others and the linking and synergies between each dimension are what makes a city smart. Moreover, this approach tries to put the citizen at the centre of the attention. In particular, it was suggested that the technological capital of a city must be usable and its applicability understandable by the community, which plays a fundamental role in making the transformation operative and capable of producing a significant impact. In fact, any investment in IT technologies or infrastructures will be useless and will not produce any relevant value, if they will not be utilized for the purpose they serve. The differences between these two types of vision are summarised by the image below.[2]



Considering all these aspects together, it seems clear that it is very hard to provide a univocal definition of the concept. In the last thirty years, many authors tried to define what lies behind the concept of a smart city and what features should an urban area have in order to be considered “smart”.

Into the recent literature is indeed possible to find different definitions, that evolved thanks to the development in IT technologies and to a deeper understanding of the concept itself. Indeed, in the beginning of 2000, Hall et al defined a smart city as “A city that monitors and integrates conditions of all of its critical infrastructures […] can better optimize its resources, plan its preventive maintenance activities, and monitor security aspects while maximizing services to its citizens”. This was one of the first definition ever provided more than twenty years ago and it shows that it had already many clear goals: connect the most relevant infrastructures, plan the use of resources, and increase the benefits for the citizens. This definition was then complemented by the subsequent generation of authors. In particular, Griffinger et al. added the features of governance and proposed the idea of citizen-centered and shaped city, while Chen stressed the importance of sensors in order to collect a huge amount of data that can be treated in order to improve the way in which a city is run. Also, there are many scholars who defined the smart city concept through the objectives they serve, such as the one proposed by Nam and Pardo: “a smart city infuses information into its physical infrastructure to improve conveniences, facilitate mobility, add efficiencies, conserve energy, improve the quality of air and water […] collect data to make better decisions, deploy resources effectively, and share data to enable collaboration across entities and domains”. Additionally, Lazaroiu and Roscia include the security dimensions which they believe a smart city can improve.[3]

As we can see, giving a univocal definition of the concept is hard, there is not a single smart city model nor definition that can be used to refer to all smart cities in the world. In fact, within the wide range of definitions, each author declines the term “smart” according to his or her vision, putting more focus on different aspects of the urban center. Additionally, it is very difficult to produce a description of the concept that can be applied to all the different geographic and socio-economic urban scenarios. However, we have to keep in mind that the smart city is an integrated project, in which each component, when operating at its best, influences and determines the performance of another one, exploiting the synergies generated by them. An example in this sense is represented by the relationship between the deployment of sensors in the streets and the degree of smart mobility in that city. Indeed, the concept is not only bounded to the deployment of IT technologies and infrastructures, but it is also related to the well being of the people and of the entire community, with the aim of improving the quality of their life. For these reasons, we will use the definition provided by Mahmood (2018), which, in the author’s opinion, best grasps the different elements and purposes of such projects: “A smart city is a new vision for urban development that brings together the various sectors of the society through the deployment of Internet of Things (IoT) and distributed computing technologies. The aim is to integrate and manage a city’s resources and processes relating to transportation, health care, commerce, education, water and power, law enforcement, etc. as well as city’s various departmental information systems. The suggestion is that the world cities are growing larger; new generations have entirely new priorities; hyperglobalization is revolutionizing how we build and deliver products and services; and technological innovation is accelerating at an exponential rate. Therefore, the ultimate objective is to develop smart living environments, improve living conditions of citizens, automate city services and processes, develop open and transparent systems, and, in general, build smarter and connected communities. Goal is to ensure that citizens' needs are met, and they are technologically empowered to affect the city's functioning following a technologically led and citizen-centered-government approach."[4]

So, according to this definition, we can say that a city can be considered smart when it is capable to perform one or more of the following tasks:

- Follows a strategic vision and in an organic and organized way, trying to coordinate as much actors as possible to act accordingly to its agenda
- It deploys IT and IOT tools as innovative support in the management and delivery of public services, to improve the quality of life of its citizens
- Uses real-time information coming from various fields and exploits both tangible resources (such as infrastructures for transports, energy and natural resources) and intangible resources (such as human capital, instruction and knowledge)
- Is capable of adapting itself to the needs of users, promoting its own sustainable development.

1.2 Core components of a Smart City

Now that we have an understanding of the main principles underlying the concept of smart cities, we will discuss in this section the set of fundamental factors that are necessary in order to make a city smart, according to the scholars and the present literature. We identify and explain its main components, that are the fundamental building blocks upon which it is possible to start and sustain the change process in the medium/long term. Also, we will distinguish them into three categories of core factors: technology (technology (infrastructures of hardware and software), people (creativity, diversity, and education), and institution (governance and policy).

- **Technological factors**: they are essential for a city in order to be considered "smart", because it is only with the help of IT tools that we can get the most value out of this particular city layout. Thus, it is fundamental to be able to generate high amount of technological resources that are necessary to monitor the present situation and forecast the future ones. However, despite its importance, a solid infrastructure is not enough for a city in order to be considered smart. In fact, there is the need of a coordinated cooperation between the main actors in this scenario, such as public authorities, private companies, voluntary organizations and, in particular, the citizen who, ultimately, have to act accordingly with smart principles in order to be able to achieve the related benefits. The vast majority of the literature has focused his attention on infrastructures and enabling technologies. This theme is strictly related with another critical issue, which is the availability and accessibility of the systems. In this context, according to Washburn et al., a major role will be played by smart computing, which is defined as “a new generation of integrated hardware, software, and network technologies that provide IT systems with real-time awareness of the real world and advanced analytics to help people make more intelligent decisions”.

In general, we can identify three main components that are necessary in order to deploy a smart city:

1. Smart interface: which is defined as the linking point between different operative systems that allows to interact and exchange information between each other’s. Example of this category are represented by dash boards, common operational platforms and integrated web services
2. Smart control system: which are all those devices that are used in order to control, monitor and optimize certain aspects of the smart city. An example of those systems is represented by all the tools that we can use in our house to control the temperature or the lights. In general, this category includes all instruments belonging to automatic control network and local operating network
3. Smart database resources: these tools allow to collect huge amounts of data, that are necessary in order to understand the actual state of the art of the city, were there are issues, what type of actions to take, and also to monitor and assess the effectiveness and efficiency of the measures taken. Examples of this category are both databases and server databases.

In such a scenario, it is obvious that all typologies of technology have the same level of importance, especially the mobile, the virtual and the ubiquitous ones. However, despite the fact that a wireless infrastructure is necessary to be present into the architecture of the city, still it is not enough to turning an urban area into a smart city, if considered alone. Indeed, additional features are required in order to have a well-operating system, that must be able to provide huge amount of real time data to the public decision maker one one side, while on the other provide as many touchpoints as possible with the citizens, in order to improve the quantity and the quality of the services offered to them. Examples of this additional enabling factors are:

1. Network equipment: all the basic tools that are fundamental in order to exploit IT but especially IOT technologies, we refer here to all the tools that allow basic interactions with the technological resources of the city, such as optic fiber channels and wi-fi networks.
2. Public access points: we refer here to all the tools that allow to enter the technological infrastructure of the city from a public space. Examples of this category are represented by wireless hotspots and kiosks
3. Service-oriented information systems: they are defined as "a type of software design that makes software components reusable employing service interfaces based on a common communication language over a network". An example of these systems is represented by the mobile apps. If we take into consideration a generic running app, it will need GPS in order to work effectively, so it uses the inbuilt GPS functions of the device.

- **Human factors:** Another relevant element of a smart project is surely represented by the levels of human capital that are available within the urban area. In fact, during the years, many scholars provided a definition of smart city which focused on the role played by the human infrastructure, the human capital and education in the deployment of smart projects. It was also suggested a 3T (tolerance, technology and talent) model by Florida, of which two are peculiar to the characteristics of the citizens.

  So, in order to have a smart city, smart people living into it are needed. This concept is related to many factors, such as: life-long learning, social and ethnic plurality, flexibility, creativity, cosmopolitanism, and participation in public life. Indeed, many of the problems that can arise with the urban agglomeration can be solved through the use of creativity and cooperation between the main actors involved. Thus, in this context, when we talk about smart city we refer to the ability to find clever solutions by creative people.

The category of human factor embraces also aspects like social learning and education. Indeed, a smart city is a center in which higher education and a smart workforce are produced through the use of education aimed at increasing the levels of human capital. This category also includes all those aspects that are related with social inclusion, soft infrastructures (such as knowledge networks, voluntary organizations and crime-free environments), and all those practices oriented toward urban diversity and increased cultural mix.

Also, education plays a fundamental role in this context. Indeed, cities that are able to create high levels of high-quality education are often the most attractive, both for public organization and also for private businesses. An example in this sense is represented by Politecnico di Milano and Politecnico di Torino, acting as catalysts within which we can find competent and well-educated students, which cooperate with the Public Authority, seeking innovative solutions to major city problems and with private companies seeking highly qualified personnel. So, in this sense, trying to interpret the smart concept through a human centric perspective "an integrated approach to connecting among entire communities, creating specific services to address city objectives, and advancing collective skills and capacities."

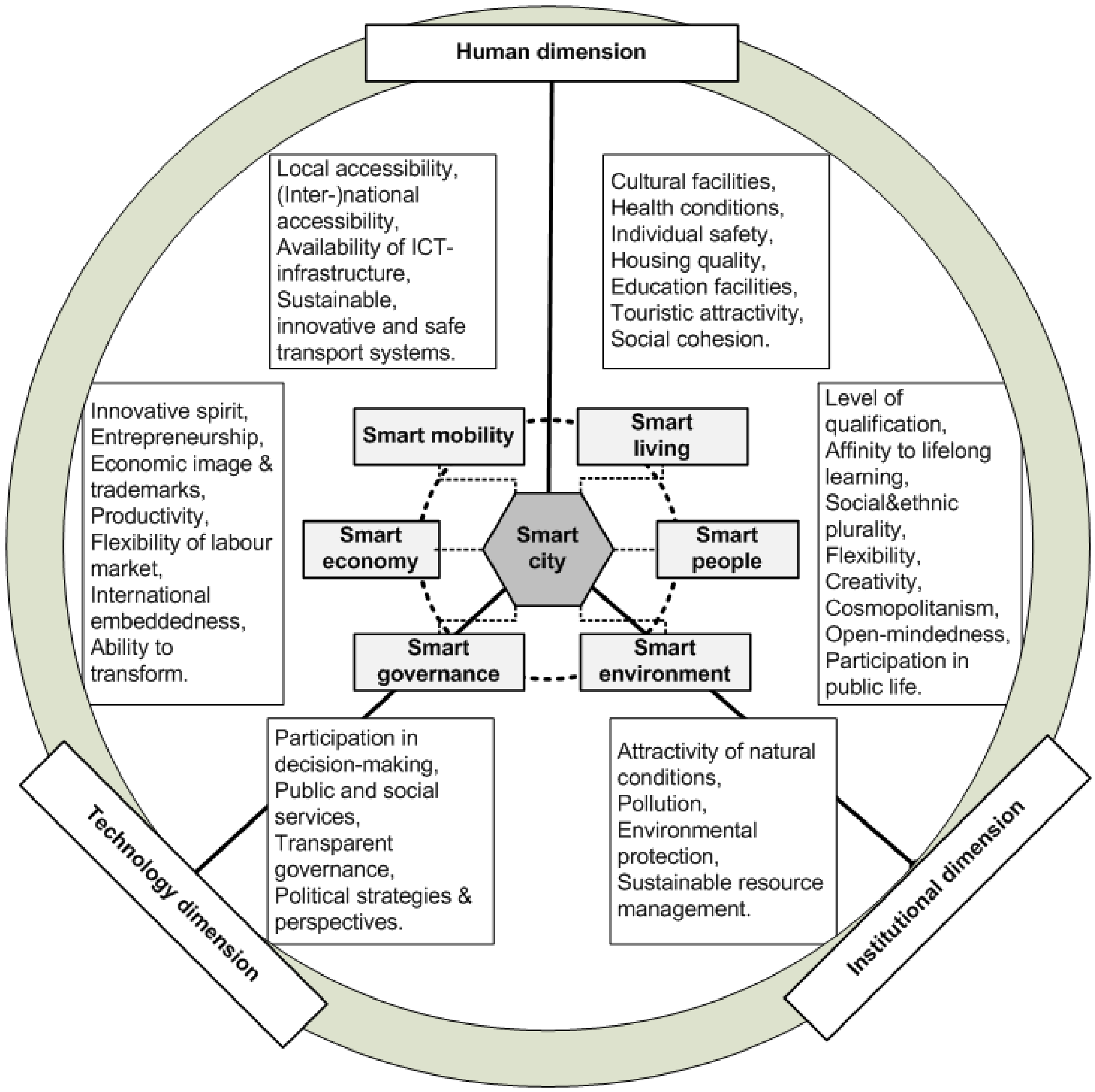
- **Institutional factors:** in order to promote effective smart city initiatives, a strong support of government and policy for governance are required. In this category, we will include a variety of institutional factors, focusing not only on supportive policies but also on the role of the government, the relationship between government agencies and non-government parties, but also their governance. It is necessary here to build an administrative environment supportive for a smart city, through the use of initiatives, fairs and workshops that can stimulate engagement and excitement among all the private and public actors involved. Additionally, in order to make the smart city initiatives effective, there should also be included here integrated and transparent governance, strategic and promotional activities, networking, and partnerships in order to spread the vision among the main stakeholders and possibly also to obtain financial resources. Moreover, a key role will be played by smart government. With this term we do not only refer to the functions related to the regulation of the economic and societal systems, but also to the capacity to create dynamic interconnections between citizen, communities and businesses in real time. Thank to this, it will be easier to stimulate and also generate innovation and foster progress in the city. So, in general, when we talk about smart government, we refer to the ability to co-operate across departments and within communities, with the goal of:

- becoming more transparent and accountable
- manage resources in an effective and efficient way
- give to the citizens relevant information regarding the decision that may have an effect on their lives

An example of practices in this sense is represented by the efforts of the government, trying to integrate their service delivery, or the establishment of offices that can support multiple services, or placing the most needed transactions on the web. In other words, a smart government is fundamentally the one that stimulate and create operations and services citizen-centric.

Another fundamental element of a smart city is the smart governance. With this term we refer to the ability to coordinate various stakeholders' engagement in decision-making and to easily access to public and social services. In particular, we can consider here e-governance, IT-based technologies that can make easier for the citizens to understand and approach the smart city initiatives, while keeping the implementation process transparent. The approach used here is to build a citizen-centric, but also citizen-driven governance. However, we have to keep in mind that urban agglomerates are complex realities, of which other types of stakeholder are also part of. So, the ability to consider all the stakeholders involved is a cornerstone into the architecture of a smart city. In fact, the initiatives that resulted as successful are the result of the co-operation between different entities, such as private businesses, public governments and the individual citizens. So, it is essential in this sense an active involvement from every sector of the community. Additionally, well-coordinated and aligned efforts are capable to generate synergies, so that the individual project can influence each other and create faster progress. The final result will be an involved, informed and trained force that is necessary to spark the transformation process of how the entire community works.

The connection and the relationship of these three dimension with the smart city universe is presented in the image below. As we can see, each dimension has a direct impact on the smart city universe and so it is necessary to pay attention to each of them separately. In fact, only an integrated approach, in which all these dimensions are evaluated simultaneously, allows to generate a coherent idea of smart city that can produce significant benefits for its citizens. On the contrary, omitting one of these dimensions of analysis results in a fragile project, perhaps based on an innovative idea, but not destined to survive in the medium to long term.[5]



1.3 Main Features of a smart city

It is undeniable that each city is unique: it has its own geographic, cultural, economic, political and cultural peculiar features. However, it is possible to discern some common characteristics to urban agglomerations around the world. In this perspective, we thus tried to create a taxonomy of the scope of application of a smart city, so that we can develop a more schematic view on the subject. The analysis outlined that a big effort was put to address environmental issues and to upgrading of key network infrastructures, such as those dedicated to transports and energy). Also, a particular focus is placed on the construction' sector, which relevance is increasing, due to the fact that a lot of infrastructures do emit pollution and due to the urbanization trend, that takes place in the most densely populated areas on the planet. We can say that all these application are more related to the tangible areas that a smart project can affect. At the same time, there are some intangible areas on which a smart city project may have an influence and an effect. Among these, we have some examples of what a municipality should provide to its citizens, such as health, education, security, cultural heritage management, welfare services and social inclusion. Lastly, we can find here the city government services and all the initiatives that try to stimulate innovation and creativity and thus, are related to the increase in human capital.

So, to resume, the proposed taxonomy will be composed of 7 areas, each of them will have many sub-area of application.

- **Smart building:** in this area, we are referring to all those initiatives that aim to achieve an improved efficiency, so that the environmental impact and footprint of every future building will be reduced. This result is achieved through the integration of systems in a domestic environment. The main areas of intervention are related with the energetic management, in which hardware and software solutions are used in order to optimize each citizen' level of consumptions. This area is often exploited in combination with home automation systems, that may help for a smarter use of household appliances but also for the regulation of heating and cooling systems. The combination of these two aspects, energy management and home automation systems, give birth to another field of application for the smart buildings, which is represented by intelligent home appliances. These devices may represent the true turning point: through the control of the most energy consuming devices of our house, we can significantly reduce the environmental footprint and impact produced. An example in this sense may be represented by the possibility to remotely set the start-up of the washing machines during times of the day when energy prices are low. In this context, it is clear that these three fields are strictly intertwined and interconnected and thus only an integrated development of each of them can guarantee the best outcome possible.

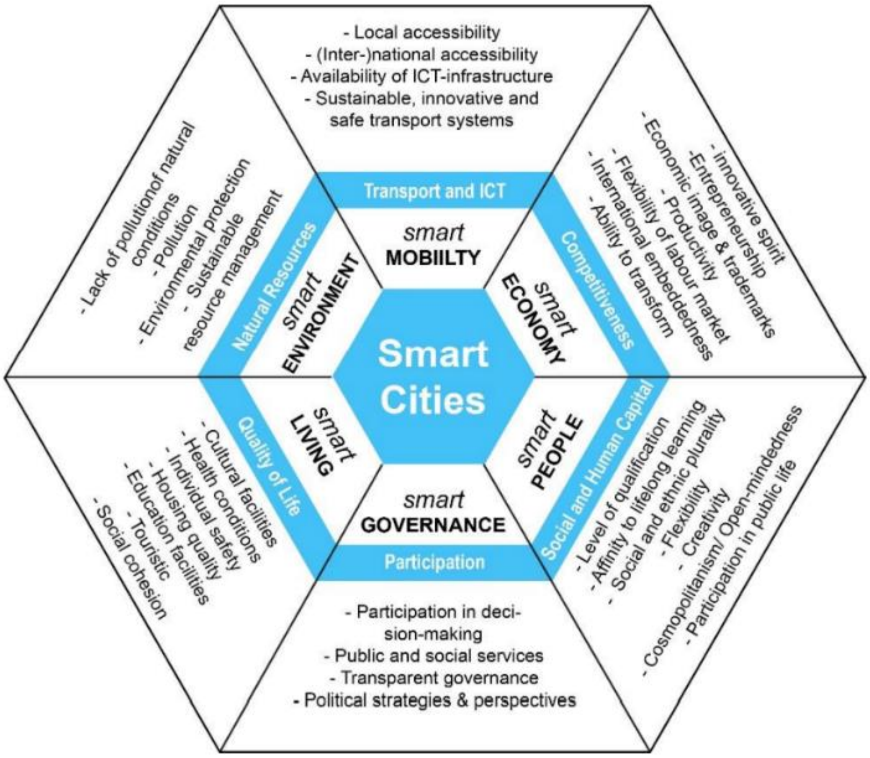
- **Smart economy and people:** here we do refer to the ability of the Public Administration to set up the perfect environment that can foster the diffusion of enterprises and people's empowerment. So, we can say that this aspect is related to a "soft" aspect, considering that very few physical resources will be employed in this area. Thus, PA investments in the deployment of ICT tools are the fundamental basis in order to create an innovative environment. The first sub-domain here is related to the ability of a Public Authority to attract and maintain a qualified human capital, but also the ability to create it from zero, through the use of education and instruction. The second sub-domain is related to the aspect of entrepreneurship of a city, which is the proxy for its economic dynamism. An example of the combination of these two sub-domains is represented by the city of Turin, in which the Politecnico University plays a big role in incrementing the human capital and also founded I3P in 1999. It is an innovative enterprise Incubator of the university that promotes science-based enterprises in connection with university researchers or entrepreneurs.
- **Smart Energy:** the objective of the initiatives of this domain is oriented to increase the efficiency of the available energetic resources, along with the research for new ones. For what regards the efficiency, a solution is represented by the smart grid, an information network and an electricity distribution network, that, combined together, allow to manage the distribution of the electric energy while minimising possible overloads and voltage variations. Another interesting field of application is represented by the public illumination, which covers a significant role in the public budgets and has many area of interventions. The second objective is related to the research for new sources of renewable energy.
- **Smart Environment:** a city that acts in defence of the environment is characterized by an improved and more efficient management of natural resources and by the management of the waste cycle. For what regards natural resources, an improved

water management may result in a reduced level of waste, along with the possibility to re-utilize all the non-drinkable water recycled in other areas, such as cleaning and/or agriculture. The same conclusion can be applied for what regards waste management, with the objective of increasing the percentage of recycled waste. In this sense, Bin-e, a Polish company, designed a smart bin that uses artificial intelligence-based object recognition to divide waste into separate compartments. This simple solution can reduce waste management costs up to the 80%.[6]

- **Smart Government:** a smart government is the one that can reduce at minimum the level of bureaucracy of a country. A high level of governmental bureaucracy represents an obstacle to the diffusion of an innovative and competitive environment, which in turn is needed in order to foster economic growth. In this scenario, the use of ICT and IOT tools may help in order to make use of the services offered by the public administration, a practice called e-Government, and in order to simplify active citizen participation in the democratic process, through the use of e-Democracy. In this context, a major role is played by all the blockchain-based technologies, that can help to improve both of these sub-domains.
- **Smart Living:** this dimension is strictly related to the services offered by a Public Administration, because both the quantity and the quality of services offered to the citizen determine the quality of life in that particular urban area. In this area of application, IT and IOT technologies are employed in order to guarantee an improved quantity and quality of the welfare services offered to each citizen. A glaring example is provided by the Health Sector, which can be drastically enhanced through the use of technology. This is especially true if we consider the devastating effect that the pandemic of COVID-19 had on our hospitals first and on our economic and social tissue secondly. Another dimension that certainly may have a major impact on this domain is represented by all those initiatives aimed at protecting and enhancing the cultural heritage. This means, on one side, give value to the cultural, historical and artistical assets that is possessed by the Public Authority and, on the other, propose a smarter use of this heritage, through services that favour tourism, leisure time and culture in general. The last dimension of this domain is represented by the instruction, a particularly sensitive issue in Italy, which can be improved through the use of technology, so that there are more possibilities for both scholars and teachers.

- **Smart Mobility & transports:** the increasing number of the world population, along with the increasing urbanization of densely lived area, make this domain extremely important. In this context, the aim is to be able to move people and goods in urban settings in an efficient and effective way, so that the negative externalities produced by traffic can be minimized. Here we can find the sub-domain related to City Logistics, which is the capacity of the public decision-maker to design a process in which there is the possibility to optimize urban logistics; in particular, the focus here is put on the movement of goods produced by private companies, with a particular attention on the level of traffic congestion created, the pollution generated, and the energy expenditure required. The second sub-domain is instead oriented toward the mobility of people in urban spaces. in this case, technology is used to develop new mobility systems; in particular, all sharing applications, such as car, bike and scooter sharing, belong to this category.

As we can see, the level of complexity of a smart city is very high. Each dimension, which is presented in the graph below, has its peculiar features that has to be coordinated with the others, so that it is possible to achieve superior results and enjoy the externalities produced by an effective synergy between these elements. The public decision-maker must therefore the capabilities to develop this new vision of the urban environment and try to infuse it within a set of policies to support the transition to a smart city. It is also important to notice that for each dimension, in order to be successful in delivering its benefits, it is possible to locate many actors that play an important role in reaching, or in worst-case scenarios in impeding the goals established. Moreover, these players possess different peculiar features, for example they can be public or private agents, which significant consequences on the amount of effort and resources that can be made available. It is thus fundamental, in a first phase, to being able to identify and distinguish between these key actors, in order to understand each one' role in the transition process. Then, it is necessary to develop a shared vision, as it is presented in the model below, so that all the relevant player act together, pursuing the same objectives. Thanks to the exploitation of a strong and effective communication, it is also possible to generate widespread commitment and engagement among citizens, thus greatly simplifying the whole process. Therefore, by identifying and exploiting these synergies, it is possible to generate cascading effects that produce positive externalities for the whole system.[7]



1.4. Typologies of Smart City

As we saw in the previous paragraphs, the concept of smart city is very broad and it is actually applied to many cities around the globe, that may present some relevant differences between each other. If we consider, for example, Milan and Amsterdam, we can see that, despite both are classified as smart cities, they have significantly different urban assets. This is obviously due to many factors, such as the geographical location of the city, the number of inhabitants, the infrastructure that is already present on the territory, along with all the economic and social variables that may come into play, like the average wealth and education level. Continuing the aforementioned example, it seems clear that the two cities have, for example, totally different infrastructures dedicated to the movement of goods and people. This is due to the geography variable: Amsterdam's proximity to the sea meant that over time the city developed one of the largest and most efficient ports in Europe. Milan, on the other hand, cannot enjoy such benefits due to the lack of bodies of water close to the city.

So, this example makes clear that a key factor that helps us in defining and understanding the concept of smart city is strongly related to the different typologies of cities that we can encounter. In fact, each city has its own characteristic structure, the result of a combination of a multitude of variables (such as geography, location, numbers of citizens etc.) which ultimately will determine its peculiarities, along with its strengths and weaknesses. This differences determine the possibility and/or the capacity of cities to manage smart technologies and attract investment oriented to development of a smart city. As an example, the differences in the physical characteristics of two cities may affect the possibility to acquire, implement and apply particular digital technologies' solutions. Moreover, the widespread tendency of the literature and the scholars to focus only on large smart cities makes it difficult to implement such projects in smaller realities due to the limited resources and infrastructure available. Another obstacle to the diffusion of smart projects may be represented by the digital divide that is already present within the cities. As an example, in Detroit, 29.7% of the population does not have access to broadband. If we compare these data with Los Angeles, in which 86.2% do have access to broadband, it is clear to understand who the greatest chance of would have successfully implementing a smart project. In this diverse and multidimensional context, we cannot find an unambiguous concept that can be applied in all realities. Smart city initiatives thus need to match the local features and circumstances in order to generate benefits. So, being able to distinguish between different typologies of smart cities helps to understand the starting point of the city, facilitates peer-to-peer discussion to find common solutions for common problems and it is very useful in designing the future evolutionary path of the conurbation.

Among the various approach that are used to classify the different typologies of smart cities, the OECD has created a system that divides them according to five approaches:

I. The level of economic growth and status of a city
II. The urban growth lifecycle

III. The smart urban innovation dimensions
IV. The goals
V. The spatial cluster analysis

We will now proceed to analyse each of these dimensions of analysis in depth, also providing appropriate examples. This will be useful in determining different categories of smart cities and identifying which profile best fits our smart project.

I. *By level of economic growth*

According to this method of evaluation, we will divide the cities according to two variables:

- developed economies vs emerging economies
- legacy city vs new city

Through the combination of all the possible combination of these dimensions, we get to four types of city. The first is "*Developed economy + legacy city*". This typology is peculiar of those cities which have a long history of development and that are in a "maturity" stage of their lifecycle, with a strong and structured economy which, in turn, shaped the set-up of the city, particularly regarding the networks responsible for the movement of goods and people. In this case, the smart city technologies will be applied directly to the existing infrastructure network, such as roads, ports and buildings, often with the final result of significantly changing it or even dismantle it. A very common phenomenon that this type of cities is experiencing is the reduced population growth rate, that in some cases, is exactly equal to zero. This is a factor that has to be taken into account for many relevant decisions. As an example, if the growth rate of the population its close to zero, it means that, in the future, there may be a higher percentage of senior citizens than of young people, thus significantly influencing the adoption rate of new technologies and, consequently, also the success rate of all projects with high technological components.

The second typology is represented by "*Emerging economy + legacy city*". Similarly, to the first type of city, also in this care most of the physical structures are already present and established, however the fact that the economy still has not reached the maturity phase means that the implementation of the technologies within the infrastructure will be less drastic than the first case. However, here it is fundamental to understand where the city is pointing to (are we becoming a commercial city, a digital city or a cultural one?), so that the technological infrastructure can support and simplify the transition from the current to the future state of the city. In this sense, a major role may be played by the private capitals and funds, that may invest their resources in improving the quality of the existing infrastructure and, allowing to the citizen a better use of it. Additionally, the main difference with the first category is that here we witness a fast-growing population, so any intervention that improves efficiency and liveability (especially those aimed at minimizing traffic and congestions) will be perceived as of great value.

The third type of city layout is defined as "*Emerging economy + new city*". This setup is typically characterized by a rapid economic growth and a high population growth' rate. Thus, investing in these situations may be very profitable both for the citizen and the investor, who may experience elevated levels of return on investment. In particular, due precisely to the rapid growth of the population, the value extracted by investors will consist of all citizens who will be new users of the proposed technologies. Additionally, these cities, considering that they do not have a deep legacy, are even more prone to the adoption of new technologies, because they don't have a physical or social structure, acting like an obstacle, that could be disrupted by it. on the contrary, the implementation of new, modern infrastructure in urban planning will determine both its economic competitiveness and quality of life in the future.

The last type of city is represented by the combination "*Developed economy + new city*". Typically, the cities that belong to this category are satellites cities, placed around mega-cities or metropolises. Given their particular position, they will naturally compete with their bigger relatives for job opportunities and, in general, their final objective will be to reach the economic growth. These cities must focus their political and economical effort towards the infrastructures. In particular, they must focus on the hard infrastructures, in order to increase the efficiency of the operations for the companies, thus reducing their levels of operative costs. Example of this type are represented by all the physical infrastructure that allow the movement of goods and people, such as roads, bridges, ports. Additionally, if the public manager wants to be successful, he must also focus on the soft infrastructures, that will bring, as a final effect, an enhanced quality of life to citizens. Examples that belong to this type of infrastructure are represented by all those institutions that foster, promote and cultivate knowledge and higher levels of human capital, such as museums, libraries, theatres and universities.

This dimension of analysis based on the level of economic growth is summarised in the table below, which, for each different type of city identified, identifies appropriate examples taken from already existing cities.

Table 1.1. Characteristics and examples of smart cities by level of economic growth

Type	Characteristics	Examples
1	Developed +Legacy	London (UK), Detroit (US), Tokyo (Japan), Singapore
2	Emerging +Legacy	Mumbai (India), São Paolo (Brazil), Jakarta (Indonesia)
3	Emerging + New City	Suzhou (China), Astana (Kazakhstan)
4	Developed + New City	Songdo (Korea), Masdar (UAE), Hafen (Germany)

Source: Macomber, J. (2016[7]), "The 4 Types of Cities and How to Prepare Them for the Future", Harvard Business Review, January, retrieved from https://hbr.org/2016/01/the-4-types-of-cities-and-how-to-prepare-them-for-the-future

II. *By stage of urban growth*

This type of analysis and distinction was first proposed in 2019 by the Ministry of Land, Infrastructure and Transport of Korea (MOLIT). The first result of this analysis consists of *smart cities in new cities*. in this case, we are dealing with projects that are applied on a large scale and are often conceived and developed almost from scratch. This type of smart city aims to solve existing mobility infrastructure problems in the area and to provide testbeds for possible disruptive smart city solutions, which can significantly change the face of the city. the ultimate goal here is to create an innovative industrial ecosystem in which highly educated and qualified personnel work for a range of industries that, working and operating in a coordinated and integrated manner, multiply the beneficial effects for citizens while reducing the negative externalities produced by their economic activity. The second category emerging from this analysis is *smart cities in existing cities*. In this case, it will be required a different approach, because the existing social and physical infrastructures will act as obstacles for the diffusion and implementation of smart city facilities and solutions. Also, the citizens themselves could represent a 'cultural' barrier to the diffusion of such solutions, as they could implement a reactionary approach to change, hindering it and trying to prevent it. In order to successfully develop a smart project in the face of an existing setup, the public decision-maker must carefully select a few areas of the city, among the most dynamic, willing to change and most likely to succeed. the goal will be to create an area that is personalised to the needs of citizens and at the same time can be lively and competitive for them. The third category identified is *smart cities in shrinking cities*. This typology is characterised by being one of the most problematic to work with, as these layouts inherit multiple problems at the urban level and lack the resources to design and implement technological solutions that could make a significant impact. The best solution available for this towns is to identify small and limited areas of vulnerability, in which the public administration is effectively and efficiently capable to intervene. It will thus be probable, in this case, that the impact deriving from the adoption of such smart solutions will be quite limited.

III. *By type of smart urban innovation*

Another methodology used to distinguish and classify the urban centres is the one proposed by Nillsen and it is based on the level of urban smart innovation: for each variable took into consideration for this analysis, it is individuated a particular type of smart project The typologies of innovation are four; specifically, they are:

1. Technological innovation: that can bring, as a final result, new products, practices and services. The *technological smart city* belongs to this category. Its main feature is that there is a strong attention and focus on the possibilities opened by the use of technology. As an example, we can consider all those applications that encourage the use of public transport or all the applications that encourage the shared mobility practices.
2. Organizational innovation: which happens whenever there is an internal improvement in any public organization. We can find in this second cluster the *organizational smart cities*. The main difference that can be found with the technological smart cities, is that the effect of their decisions and actions may not

produce a tangible effect for the end-users. In fact, the main focus of these municipalities is directed toward changing the day-by-day operations in order to obtain and enhanced efficiency and productivity of the organization. Another typical feature of this particular layout is the fact that they may have a project-based approach. Considering that the projects have limited durability, this means that the scope of their initiative is incremental. Thus, more complex projects and major effects will be achieved only after the accomplishment of smaller and simpler ones.

3. Collaborative innovation: which is based on the triple helix model. According to this view, in order to obtain economic and social development, a continuous interaction between academic world, private business sector and public sector is needed in order to be able to exploit these synergies. In this category we can find the *collaborative smart cities* which canalize their effort in order to co-ordinating at its best all the actors involved in the aforementioned triple helix model. The key for the success here is represented by an open and interactive governance process, which, in turn, will stimulate the entrepreneurial role of each actor and will increase the level of interaction between each participant of the network. For this reason, the actions taken by this particular smart layout will have a more radical scope than the previous two.
4. Experimental innovation: which is obtained through a citizen -centric approach. The *experimental smart cities* belong to this last category. They are characterized by the wide diffusion of living labs, which are essential tools, necessary in order to achieve urban innovation. The efforts and the resources are oriented toward a story-telling narration of the innovation, rather than a technology-oriented point of view, through the combined use of the aforementioned three categories of smart cities.

Table 1.2. Types of smart cities by dimension of urban innovation

	Characteristics	Incremental vs Radical innovation
Technological	New technological practice and services	Incremental
Organisational	Internally in the government; project-based	Incremental
Collaborative	Public-private networks and partnerships	Radical
Experimental	Innovative urbanism; citizen centric	Radical

Source: Nilssen, M. (2019[8]), "To the smart city and beyond? Developing a typology of smart urban innovation", Technological Forecasting & Social Change 142, p.98–104.

IV. *By goal*

Another typology of analysis is proposed by the Korean Research Institute for Human Settlements. According to this method, the newest smart projects have emerged in order to accomplish a pre-determined goal, such as reducing the climatic footprint of an urban conglomerate or to foster and boost industrial and economic innovation. So, after considering and scrutinizing more than 60 smart cities in Korea, the KRIHS divided them into three categories:

- *Smart city equipped with advanced infrastructure:* this particular layout focuses his attention toward the efficiency through which a city is run. Indeed, their main objective is reaching a high level of integration between ICT technologies and physical infrastructures, already present on the territory. The main dimensions affected are, for example, transports, safety and built environment
- *Platform-centred smart city:* in this case, the attention is posed on the integration of different information systems that, previously, operated in an independent way one from each other. An example of separated information systems may be represented by the mobility and transport networks and the energy network, which can be coordinated so that the information produced by each system, combined with those produced by the other on, may stimulate activities with significant impact on both the dimensions. The main tools through which we extract this value are smart city control centres and smart city platforms. Through them, it is possible to create synergies between the existing datasets and service infrastructure.
- *Smart city for innovation space:* this urban arrangement is definitely the most oriented and prone to radical innovation. In fact, the main purpose of this layout is to identify and isolate cutting-edge technologies and, simultaneously, to sell them to the related industries, so that new types of commerce can flourish and emerge. The fundamental key in order to reach success is represented by a strong, steady and long-term oriented partnership between the public sector and the private one. This is also aligned with the idea that, through breakthrough innovation, there is the possibility to not only solve urban problems, but also to increase earnings for the private sector, thanks to the new markets that such opportunities generate. In this

scenario, the role of the public authority is, on one side, to provide the financial resources necessary to develop new solutions and, on the other, to modify the current legal regime, so that it is possible to create an environment stimulating and facilitating innovation-oriented scientific research.

It is also interesting to see that, based on this research, other authors and scholars like Lee and Chang proposed two different types of smart city, depending on the goal that they are trying to reach, along with their main features and operating methodologies. The first category that they identify is the *problem-solving smart city*. The final result that this urban category aims to reach is the implementation of cost-efficient solutions for urban problems. The method that can allow that is based on the use of individual solutions for urban issues on one side, and on living labs and sharing innovative solutions through the city networks on the other. This urban smart layout is easy to find in city centres and shrinking cities.

The second typology of smart city identified by the researchers is defined as *opportunity creating smart city*. Its main concern is to foster and develop an innovative environment for private industries. The way to achieve this goal is represented by deregulation, but also on a sloid and widespread digital infrastructure, which bases its activities on open data platform for industries. These particular urban conglomerations can be encountered both in greenfield cities, which are brand new urban areas built form scratch, and in brownfield cities, which are existing projects into which this particular type of smart project is grafted. In particular, considering the latter, a possible example may be represented by the creation of a sharing economy that may represent a more efficient opportunity for the brownfield projects. In general, the main idea in this case is that smart cities can help to create and to identify opportunities from existing resources in physical space. If, on the other hand, we take into account the possibility of creating new and radical economic opportunities, then we will prefer the greenfield-oriented set-up, because a whole new IT and communication infrastructure is necessary to allow to the urban space to adopt and embrace the new technology.

V. *By spatial cluster*

The last category of analysis is the one proposed by Griffinger et al. in 2014. Starting from the author's analysis, a taxonomy of the European small and medium-size urban areas is created in order to be able to benchmark those who share common characteristics. The research has been conducted on a sample of 81 cities and 28 domains. Each city was assessed according to its ability to meet one of the above-mentioned application areas. A negative score corresponds to a below-average performance in the field of analysis considered, while a positive score indicates a better outcome than the average European city. The results of this assessment are presented in the chart below.

Table 1.4. Clusters values according to the 6 smart city key fields

Cluster	Smart Economy	Smart Environment	Smart Governance	Smart Living	Smart Mobility	Smart People
1	-0.73	-0.84	-0.44	-0.57	-0.92	-1.08
2	-0.44	-0.17	-0.71	-0.67	-0.51	-0.55
3	-0.39	-0.10	-0.29	-0.13	-0.28	-0.45
4	0.68	0.22	0.01	0.88	0.60	0.45
5	0.27	0.02	0.10	0.19	0.26	0.24
6	0.13	0.46	0.65	0.21	0.15	0.62

Note: 0 = mean of all cities. Negative values refer to a cluster performance below average in the respective key field; positive values indicate that this cluster performs higher than the European average city.
Source: Giffinger, R., Haindlmaier, G., and Strohmayer, F. (2014[11]). Typology of cities, Planning for Energy Efficient Cities, retrieved from http://pleecproject.eu/downloads/Reports/Work%20Package%202/pleec_d2_2_final.pdf

Thanks to these data, the author identified six spatial cluster, which are group of urban conglomerates which share similar key field features. Moreover, the analysis can go even further: in fact, each city it can compare its performance with that of the cities belonging to the cluster most similar to it, so that it can be clear which are its strengths in terms of performance and which areas it should focus on for improvement.

- Cluster 1: the cities belonging to this cluster generally have a poorer performance than the average in all the six fields of analysis considered. In particular, the area dedicated to the training and education of citizens and all activities aimed at increasing the current level of human capital in the city, which corresponds to the smart people dimension, is very lacking. The dimension in which is registered the best performance (or at least, the least bad) is the one related to smart governance practices. We can find in this cluster many Romanian cities, including Craiova, Sibiu and Timisoara
- Cluster 2: even the members of this cluster are also characterised by a generally poor performance, particularly if we consider the dimensions of smart governance, smart living and smart people. On the other hand, better results are recorded for the smart environment dimension, in which these cities always perform negatively, but with

values very close to the average recorded. Examples in this cluster are represented by cities of Latvia and Lithuania, such as Liepaja and Kaunas.

- Cluster 3: again, the urban agglomerations that fall within this cluster generally have a lower average performance than that of the major European cities, as denoted by the negative values in the table, which are, however, much closer to the threshold (the zero value) than the first two clusters, which were very far from this "target value". in addition, the smart environment and smart mobility dimensions perform very close to the European average value. It is interesting to notice that, in this cluster, we can find many Polish cities like Bydgoszcz, Rzeszow and Szczecin but also many Italian cities fall into this category, such as Ancona, Padova, Perugia, Trento, Trieste and Venice.
- Cluster 4: from this point, we begin to see the "best in class" cases. As we can see from the table, almost all of them perform significantly higher than the European average. For example, the smart living and smart economy dimensions are very close to value 1, indicating an exceptional level of performance for these areas of analysis. On the other hand, it is interesting to note that the results obtained for smart governance and smart environment are positive (greater than zero) but significantly lower than the other 4 dimensions and very close to the European average value. Belonging to this cluster are the city of Luxembourg and the Austrian municipalities of Graz, Linz and Salzburg
- Cluster 5: it is interesting to note that the cities belonging to this group have lower performance values than the highest values recorded in cluster 4, i.e. smart living and smart economy. however, this cluster shows greater stability: all values are positive and without large value swings between one dimension of the analysis and the other. We can find here mainly northern European cities such as Eindhoven, Brugge, Leicester and Innsbruck, but also the Italian city of Verona.
- Cluster 6: in the last cluster we find all those cities that perform positively and clearly above the European average value of zero. In particular, we can see that the dimensions "smart people" and "smart governance" present very high values, while, considering the dimensions "smart economy" and "smart mobility", although the values are greater than zero and therefore higher than the European average, they are nevertheless rather low when compared to the average values of the same

cluster. This indicates the fact that, despite the excellent performance of the cities in this cluster, there is still room for improvement. Examples of cities belonging to this cluster is represented by many French municipalities, such as Montpellier, Nancy, Clermont-Ferrand and Pointiers.[8]

1.5 Tools and Methodologies to finance a Smart City project

In this section, we will present a list of the main financial instruments that a public government can exploit in order to fund and nurture smart projects. Moreover, we will discuss strengths and weaknesses of each tool considered. It is important to pay attention to the fact that the tools that will be discussed in this section are mainly usable in the United States and the European Union, although very often the names used may be slightly different. In fact, it must be taken into account that the laws of each country may hinder or make it impossible to use certain funding sources. The public decision-maker of the future will therefore have to carefully analyse his or her own legal system in order to be able to identify those instruments that are in accordance with the dictates of the local law.

It is also necessary to keep in mind that, despite the effort put in, there is always the possibility that the projects may fail and thus that success is not always guaranteed. This scenario may happen for a series of reasons. One of the most widespread and well-known, is represented by the market failures, which, in turn, cause an inefficient distribution of goods and services in the market. In fact, the current structure of competition of a particular geographic area, defined by past economic activity and the intrinsic characteristics, may determine a hereditary imperfect competition and an unequal reallocation of resources. Another scenario that can occur is the mismatch between the funds raised and the smart project model. The cause behind this inefficiency relies on the fact that funds may be not structured or timed accordingly with the roadmap of the project, causing an increase in fixed costs, with a reduction in the overall project quality. This particular problem arises especially when the proposed smart project does not respect or take into account the geographical and cultural characteristics typical of the location where the experiment is to be launched. An example in this sense is represented by the city of Bangalore. For the city in southern India, it was decided to apply a smart city model very similar to that of Silicon Valley, as it had achieved great success on US soil and it was thought that it was sufficient to copy and repeat what had been done well in the past to achieve positive results again. Currently, the project is obtaining good results, but it grew very slowly, due to the fact that the concentration of technology-oriented entrepreneurs in India is significantly lower than the one of the United States.

Also, the aspect of accountability plays an important role for the well being of the project. With this term, we refer here to all the tools and instruments that report on the status of the development of the project and on the achievement of the pre-determined objectives, along with the impacts produced by these goals. In this case, it is important to mange the expectations of all the stakeholders involved in the project. Not being able to do it properly may cause problematic situations, such as the widespread problem of the mismatch of the time horizon between the project and the financing tools, with the latter being often too brief for the stakeholders.

Government-based financing tools: in the majority of the cases, the funds are supported through the tax collection, which represent the main source of revenue, so that it is possible to pay for a plethora of services that the citizens expect to receive. However, usually general funds are very few and allow only to pay for the operating expenditures. Also, many of the smart projects require infrastructural upgrades that will last for very long periods of time. In order to protect its citizens, the public authority maintains also capital funds, which are separated by their operating funds and are utilized in order to finance long-term investments, usually regarding infrastructure building or upgrading, whose duration extends over a period of several years. According to this model, the government issues debt instruments, with the promise to repay the full amount, plus some interests. Normally, the payment takes place when the lifetime of the infrastructure financed expires. In this group, the most well-known and widely utilized instrument is the government bond

- *General Obligation Bonds:* this category of bonds is for sure one of the most common and wide-spread financial instrument. They are used to finance basic infrastructure investments, that are disposed at a local level. Examples of structure financed through these means are the building of a new park, a city hall, a new science lab, a library, a school etc.

In this framework, the public authority issuing the instrument guarantees the emission of the bonds with the credit of its jurisdiction. So, through the use of tax revenues to repay the debt, the bonds grant today a starting capital that can be dedicated to the construction opera and will be repaid in the future years, during the life of the asset built. Also, if the infrastructure financed is proved to bring significant benefits for the public community, there is the possibility that these tools may be tax-exempted. This is especially true in the United States, where interests on the bonds issued by a local government are tax-free. The downside associated with these instruments is that, considering that the risk associated with these instruments is close to zero, the returns for the investors may not be very high.

- *Revenue Bond:* this is another popular way to finance smart projects. The main difference with the General Bonds is that, while the latter is guaranteed by the money of the taxpayers, the former is paid from the revenues coming form the economic activity of the financed asset itself. An example is represented by the public parking garages, which can exploit these instrument, because the fee paid by the users will be employed to cover the capital and the interest share. The main difference with the General Bond is thus that, in this case, we do not have the certainty that the debt will be fully repaid, so the risk associated with these tools is the under-use of the service offered by the public authority, which in turn causes the impossibility of fully repaying the debit contracted. This means, obviously, that the risk associated with these financial tools will be higher than the risk associated to the General Bonds.

  On the other side, very similar to the General Bond is the fact that also these tools may be free of federal taxes, if their public utility for the community is proven.
- *Industrial Revenue Bond:* in this category are listed all the instruments that usually are issued as part of an economic development program. In particular, the public authority issues this financial tool and the income generated will be given to a private firm for development. An example in this sense is represented by capital improvements, expansions of the firm, facility enhancement or maintenance and renewable energy-oriented and energy efficiency upgrades. In this scenario, the responsibility for repaying the debt lies with the private companies, while the municipality is exempted from any obligation to repay the bond issued. The jurisdiction will maintain the assets in its portfolio, as a collateral until the debt will be discharged. For this reason, a common

feature of the IRB is that it does not carry property tax and thus it is often seen by the private companies as a significant cost saving. This explains why local governments often use this tool as an incentive in order to facilitate business expansion for the incumbents and relocation for the new entrants in their geographic area. Again, also in this case, the instruments issued are tax-exempted, thus firms can get lower interest financing through these tools, making the alternative even more attractive for private businesses.

- *Green Bond:* with this term we refer to all instruments that are issued in order to fund specific projects, such as clean power, renewable energies and carbon-reducing ones. These tools are often seen as more appealing than the bank loans. This happens because of the main feature of the Green Bonds: they offer longer and more extended maturity periods, a stronger third-party credit, and more flexible ways to reach an agreement between the parties. Also, these tools grant numerous additional benefits. For example, they prevent form the use of direct investment' tools, with which is difficult to operate, because of the local regulatory risk and the technological one. Moreover, another attractive feature is that Green Bonds allow to meet the investor demand and needs, which, in recent years, has shown a trend of strong interest in environmental issues, along with a high growth rate of the clean energy industry. In line with this thinking, green bonds also allow environmental, social and governmental criteria to be integrated together within the portfolio, thus communicating one's commitment and interest in these issues. Combining these last two aspects, it is clear why these equities enjoy very high standards and credit ratings.
- *Social Impact Bond:* this type of instruments is very different from the classical bond type, in which it is offered a fixed rate of return. In this case, the value of the capital is determined only when the bond reaches its maturity. In particular, the payment depends on the social outcome on which the investor and the issuer have agreed upon. The yardstick used with these instruments is based on the quality of the service provided to citizens and the results achieved by these efforts, rather than focusing on the number of people who used these benefits. Therefore, the risk in this context falls entirely in the hands of the private investor who must succeed in ensuring some improvement in the current level of services offered. Thus, if he succeeds in achieving his goals, then he will be able to enjoy the payoff guaranteed by those bonds. Conversely, should he fail to succeed, the investor's loss will be equal to the amount initially invested in the bonds. In

conclusion, these instruments prove to be interesting, if we think of using them as an incentive mechanism for private business, so as to incentivise companies to implement actions that can benefit the public community. On the other hand, we have to keep in mind that these instruments are new and have a limited performance record, so we are not really aware of all the advantages and disadvantages associated with such instruments

- *Public Benefit Funds:* these financial instruments have emerged as a result of the restructuring of the electricity production and distribution industry, which took place in the end of the '90s. So, it is clear that these tools will be utilized in order to foster an entrepreneurial culture, oriented toward energy efficiency and renewable energy. Also, they contribute to the government communication, in the sense that they are used as signals of the intention of the public authority to focus on issues related to the better use of available energy and the search for new renewable energy sources. These instruments consist of funds generated through a surcharge on his energy bill, paid by the citizen, independently of who the energy provider is. This additional tax ensures that financial resources are available to fund investments by publicly managed efficiency projects. The main drawback associated with PBFs is related to the way the funds generated by these securities are allocated. In fact, public authorities often see these instruments as an opportunity to restore public finances and, in particular, to cover budget holes. Although their ostensible purpose is therefore to be used for projects oriented towards a better use of energy, very often they are entirely controlled by legislators, exposing them to the risk of being raided by the public authority and to be reallocated for other needs.
- *Linked Deposit Program:* these financial instruments are closely linked to the role of the manager of public resources. In fact, when the public administration is faced with a budget surplus, the treasurer can use these surplus resources to make low-risk investments to increase the financial resources available to the city, which in the future can be allocated to development projects or to cover possible budget deficits. Linked Deposit Programs are an example of the tools belonging to this low-risk, low-reward category. On the practical side, with this instrument, the treasurer places its resources inside a financial institution which will offer to him a lower interest rate. In turn, the institution gives this money to a borrower, who will be then in charge of the return of the money, once it has earned revenue from its economic activity. Therefore, this financial

tool is able to bring benefits to both parties: on one side, the government can experience lower administrative costs while, on the other, the borrower receives a capital amount, that can employ for capital-intensive projects, at a lower interest rate. The only limitation of LDPs is that you can exploit this financial tool only for a specific set of projects, that can vary from a country to another. Thus, a thorough analysis of the legal system in force in your state is necessary to understand whether it is legally possible to use and exploit such tools.

- *Energy Efficiency Loans:* another interesting tool that is experiencing an increase in the number of user is represented by the Energy Efficiency Loans. They consist of low-interest debt instruments that can be used by those who want to upgrade the energetic profile of their homes. Indeed, the idea is that, through the exploitation of these means, it is possible to lower the barriers for all those households who are intentioned to implement solutions that can increase the home' energy efficiency. Examples in this sense are more efficient heating and cooling systems, the adoption of a water recycling equipment, the increase in the level of household' insulation, interior renovation work to retain heat in the house and prevent heat loss to the outside. The mechanism is simple. the government, or a bank associated with it, generates the loan and the government resources are given to the borrower who will use them to cover the costs of purchasing and implementing the necessary solutions for his home. Thus, taking advantage of the fact that the capital made available comes from the public authority, it is possible to obtain a lower interest rate than the average market rate, cover inflation-related expenses and, at the same time, generate a small return on the investment made
- *Property-Assessed Clean Energy:* this instrument allows to the householders to borrow against their property taxes in order to obtain the resources necessary to cover energy efficiency improvements. The debt is repaid through an assessment of the property, which is the object of a contract between the government and the property owner. In this way, it is possible for the householders to pay for energetic improvements, thus reducing the actual level of their costs, with no initial investments. If there is a missing payment, all the capital and interest share that are to be paid will form a legal constraint on the property, until the debt is completely discharged. It is interesting to notice that such tools have the same priority level as the real estate taxes (or, they may be one step below).

Thus, this will give them priority over any non-tax constraint, such as the claims of the mortgage holder.

- *Greenhouse Emissions Allowance Auctions:* this category represents an interesting opportunity for future use. The idea is to recognize and quantify the market costs associated with environmental problems.
  The mechanism is the following: a country groups its total emission allowances and sell them in an auction and it becomes an entity that will use the market in order to regulate the levels of greenhouse gas emissions. Therefore, by putting a cap on the industrial emissions and by selling them to the market, the costs associated with polluting substances is internalized in the operations of the industry. In turn, the price of emissions is passed to the consumer, who will have to pay higher prices for the same goods. In this way, by giving to the negative externalities a value and by forcing the entrepreneurs to take into account these costs, the government has created an economic incentive to reducing their emissions levels. Additionally, the State can go even further, by using the resources generated by this "pollution tax" to provide funds for clean energy projects that can overcome pollution emissions by those companies that have not adopted such solutions.

Development exactions: here we can find another set of instruments to finance capital projects, exploiting the regulatory power of the public authority that can force the developers to pay for the infrastructure services that they will utilize. In particular, these development exaction tools take the form of a financial constraint, which is imposed on all those who contribute to helping local governments by paying the marginal increase in costs and bearing the load burdens that are generated by each development initiative. The exactions belonging to this category are classified as 'impact fees', requiring to the developer to pay an amount equal to the impact that the development brings to the community. Moreover, it is also possible to re-utilize the resources generated through these tools to build additional public infrastructures and facilities and design and implement new services, that become necessary when a higher development level is reached. So, these fees can be exploited to implement new policies and plans for a sustainable growth.

The idea in this case, is to protect the community from the negative externalities that a growth process may bring with itself, especially when the project it involves a large and wide geographical area. Additionally, these tools allow to pass a fraction of the costs associated with building and implementing an infrastructure to the developer, with the intention to synchronize the payment of the whole infrastructure. These instruments are gaining popularity to help to provide funds for stimulating the growth on public infrastructures. This happens because governments are experiencing budget shortfalls, cuts in state aid and the increasing public unwillingness to raise tax rates. However, we have to keep in mind that the public authority has to respect the legal constraints that forbid to pass certain threshold amounts along with the possible indirect consequences that may arise. As an example, we may face an inter-generational inequity when the newcomers don't pay elevated fees, while the developer is paying for the vast majority of them. Therefore, in order for these programs to be effective, a long-term analysis of the needs of the citizens, along with n in-depth analysis of the means by which these objectives can be achieved.

- *Developer Dedication Requirements:* these particular requirements are often located into town ordinances, because they act as guidelines for the land use and zoning regulations that are necessary in order to foster urban development. Usually, the developers are commanded to give their private land or facility that will be exploited for public use. The underlying logic is that those who already are residents should not provide financial resources to the developers who will attract new residents. In fact, the additional costs of the new infrastructure will have to be borne by the developers and the new citizens who will inhabit these complexes. The particular financing mechanism of this instrument makes it clear to us why some have considered applying it to smart growth technologies. More specifically, a municipality might require that roads around the development area be built with special, sustainable materials, or that new construction not occupy excessive space, or require the construction of systems for recycling water that would then be used to irrigate public green areas. With these measures, it is possible to internalize the costs linked to the environmental footprint produced by the development process. In this case, it is of extreme importance that the developer keeps into account the requirements of the nearby communities. In fact, if their needs remain unsatisfied there is the possibility to generate a backfire, with communities that can give rise to tenacious resistance.
- *Tap fees:* this is another way that the municipalities exploit in order to cover the costs of development. These tools are utility connection fees and are used to recover the cost

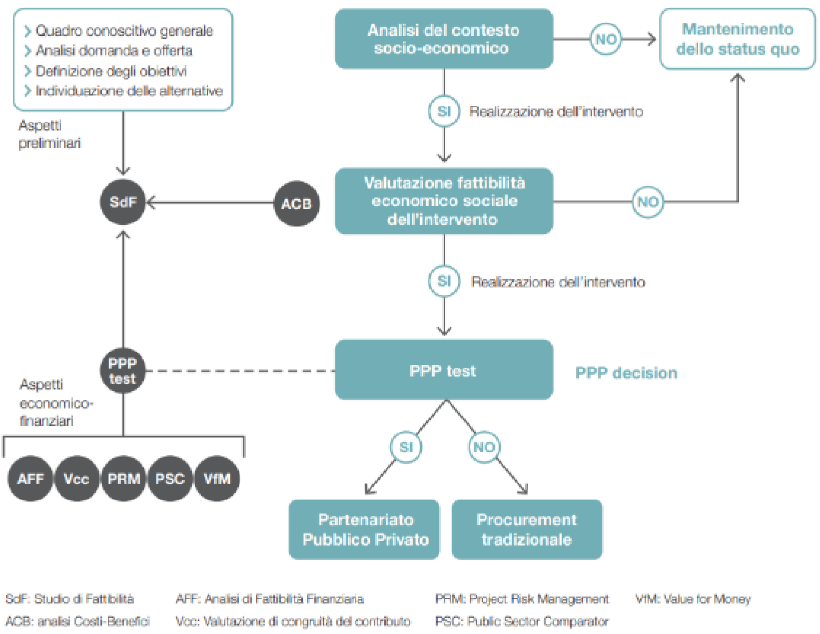
linked with the integration of new development solutions into existing buildings and infrastructures. the main purpose for which these instruments are used is to repay the costs associated with water networks; in particular, the costs of joining a new water line to the existing water network are covered

- *Linkage Fees:* the third type of exaction is represented by the linkage fee. In this category, we can find all those instruments through which a municipality charges a developer, computing the fee based on a fraction of the asset's sale value. Thus, it is immediately possible to spot a difference with the first two fees aforementioned: linkage fees are connected with the secondary effects related with a development process, while the others are calculated and based on the direct costs of it. An example of the use of such a tool is that a public organization may charge a house developer, basing on the amount of traffic that the new building has generated. Or, again, ask an exaction to the commercial developers so that with their financial resources it is possible to provide funds for affordable housing, so that all the future workers of the new infrastructure can live in the community close to their workplace and at a cheap price
- *Impact fees:* in this category, we can find all the exactions that are put on developers in order to fund additional service capacity that the future development process will bring with itself. Once again, the objective of these fees is to cover the new costs that emerge as a result of a development process and ensure that they do not burden the already established local community. In principle, this tool was designed to offset environmental costs associated with development, but today they have a much broader area of use: in recent years, they are also exploited to cover the costs of the additional infrastructures that a urban development process needs, such as the construction of new transportation infrastructures or educational ones, like schools, libraries and universities.

The co-operation of the Public and the Private sector: in this category, we will focus our attention to a more collaborative and cooperative viewpoint, in which public entities and private firms reunite together, pooling resources and combining efforts to complete a common project. This practices are receiving an increasing attention from the public. The main reason behind that is due to the fact that, on one side, private organizations often can rely on substantial resources: financial capitals, human capitals and knowledge and technological ones. On the other side, the public authorities may bring with itself many advantages for the private sector, such as the access to certain public spaces or the possibility to exploit some level of tax exemption. The main challenge that has to be faced within this category of instruments is being able to discern which part of the service offered is more in line with the characteristics of the private sector, which can therefore offer a superior service, and which part should instead be the responsibility of the public authority.

- *Public-Private Partnership:* also called with the abbreviation PPP, this tool consists of a deal sealed between a public entity and an organization belonging to the private sector, in which each organization will exploit its own knowledge and assets in order to delivery a pre-determined set of services to the citizens. The main features of this tool are that it is usually executed through a long-term contract between the parties, in which it is possible to find the specifications of the project' expected performance outputs and not the required inputs. The payment that the private entity will receive may be executed by the general public, the public administration or both. It is thus possible to distinguish between attractive investments, in which there is the possibility to generate an income thanks only to the citizens' contribution, a medium-attractive group, in which a small contribution by public authorities is required and low-attractive group, in which the services offered by the private organization is paid completely by the public administration. In order for the PPP process to start, it is necessary a preliminary project feasibility study, with the objective of passing from a general idea into tangible and specific investment proposals. For this reason, a deep cost-benefit analysis, ascertaining the economic viability of the future investment against the public benefits obtainable. Once a positive opinion has been obtained, the public administration must carry out a series of further analyses. The first is the financial feasibility analysis that judges and examines the financial equilibrium of the proposed investments. Then comes the contribution adequacy assessment, in which the level of the public body's financial participation in the project is questioned. The last round of analysis is finally represented by the Project Risk Management, in which the feasibility of the project throughout its entire life cycle is assessed, and the Public Sector Comparator, a tool with which an attempt is made to quantify the Value for Money of the project. This value results from a comparison of the cash flows generated if the project were managed and implemented directly and the revenue generated if PPP were used instead. This complex and articulated procedure is schematised in the image below

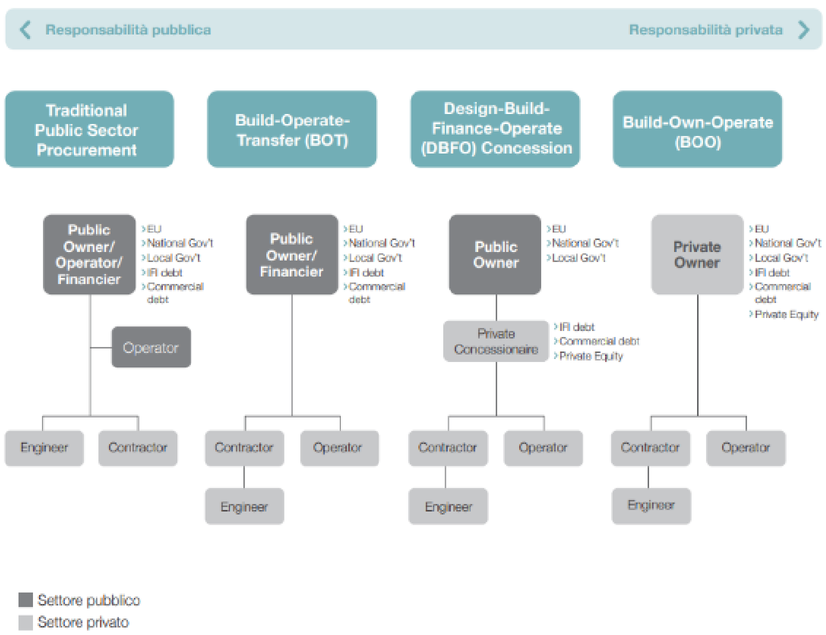
Figura 9 – Percorso decisionale della PA sui PPP



Fonte: Unità Tecnica Finanza di Progetto, 2010

- Moreover, it is possible to build tailored contracts, that are shaped according to the typology of the project considered and according with the actors involved. In fact, every PPP has, in different shares, all these elements: Design (D), Finance (F), Build (B) and Operations and Maintenance (O&M). So, by combining all these elements in different proportions, we can thus identify four typologies and models that the PPP can assume. The first is represented by the traditional procurement which is the traditional procedure in which the public authority contracts out with the private sector for the design and the construction of a specific public utility opera or infrastructure. The second category is called Build-Operate-Transfer (BOT). It is based on a concession contract between the two sectors involved, covering the design, construction, operation and maintenance phases of the infrastructure. This particular type of contract means that it is only the users who bear the cost of the entire work. In this case, therefore, there is the advantage of aggregating different functions under the same operational unit. The third form that a PPP can assume is called Design-Build-Finance-Operate (DBFO). According to this typology, the main difference with the BOT contract form lies in the fact that, in this case, the contractor bears with himself the funding risk of the opera, until the contract is fully expired. The last type of PPP that it is possible to work with is called Build-Own-Operate and, in this case, the property of the infrastructure that is built, once that the contract is fully executed and thus expired, will remain into the hands of the private firms who participated. Usually, this form of agreement is used when there is coincidence between the entire lifecycle of the object of the contract coincides with the concession period. All the types of PPP just discussed are presented in the image below, which allows us to fully understand, on the one hand, the main characteristics of each of the four forms that PPP can take and, on the other, allows us to analyse and understand all the distinguishing elements that separate each type from the other. However, we have to keep in mind some of the challenges that this particular form of contract brings with itself. One of the most apparent is represented by the complexity of the contract itself: in fact, structuring the entire PPP in order to spread the risks is very complicated, along with the necessity to have both public and private actors with the same motivations and aligned objectives. Also, the public authority must recognize and respect the private motivations, that often are oriented towards enhancing the profit' levels and thus they must put in practice an efficient and effective control and oversee system and be also able to include the costs arising from this monitoring activity within the project' overall budget.[9]

Figura 10 – Modelli di PPP



Fonte: Commissione Europea, 2009

- *Pay for Performance:* this type of contract is very close and similar to the aforementioned social impact bonds, and it is widely used to provide funds for energy-savings or energy-efficiency projects. Usually, a partnership between private and public entities is formed, with the goal of implementing a new and more efficient technology or a more sustainable one. It will be the task of the private entity to provide all the necessary financial resources to finance the new equipment and technological solutions, to finance their implementation as well as their maintenance. The role of the performance-based contract will be to reward the private company for its efforts by offering it a reward, the amount of which will vary according to the amount of savings generated through the implementation of these new technologies. Usually, such savings are guaranteed and often, the resources generated by this project easily cover all the expenses and costs associated with the project. Should the economic value of the energy savings not exceed the project costs, it will be up to the private company to pay the difference. The immediate benefit that we can see is that, in this case, the owner will receive the rewards coming from saving energy consumption and, at the same time, it will not employ its financial resources through an investment or the assumption of any form of debt. However, there are also some drawbacks: usually, the projects funded with this tool are very expensive and show an inferior capital efficiency. Additionally, the owner will also have to pay higher interest rates, on average they are two to three times higher than the performance contract financing (which is also tax-exempted, unlike the pay-for-performance contract)
- *Catastrophe Bonds:* this particular type of security was first created in the early 1990s to cope with increasingly frequent and increasingly violent hurricanes. Since insurers refused to bear the cost associated with such natural catastrophes, they decided to issue these bonds to private investors. Faced with a high risk of investment failure, some investors agreed to subscribe to these contracts because they offered extremely high returns. Although these instruments have not yet been issued in connection with a smart project, it is possible to see possibilities for future applications. Considering that natural disasters will be more and more present, less predictable and therefore potentially more damaging, and considering the spread of renewable energy markets, it is plausible to imagine the use of such bonds to help large geographical areas at risk, while at the same

time implementing smart infrastructures in these areas to increase their resilience to the force of nature.

Leveraging the private sector: the last category of instruments that we will analyse is represented by all the instruments that the private firms alone can bring on the table; being able to attract a growing number of entrepreneurs is today's main challenge for the public authorities. For the public entity, this tools are very useful when the government needs to diversify the risk embedded in their portfolios, by passing a part of those risks to the private sectors. Moreover, commercial businesses are well-known for having larger economic resources to invest that can be used to produce broad effects not only for the public welfare, but also for the market itself. For the private entities instead, investing in new technologies can signal to the customer a specific attention of the company toward this aspect, thus attracting new consumers. Additionally, the cooperation with the public governments allows to find possibilities to reduce costs, such as a reduction on the tax payable.

- *Debt Service Reserves:* these reserves allow the government to accumulate financial resources today, which serve as collateral, should it be necessary to repay the principal and interest portion of a bond in the future. This instrument is also useful for the issuer of the bond, because it allows him to count on an additional guarantee that increases the security of the bond and thus enables him to offer it to a wider audience. Such instruments can be used for the aforementioned Clean Renewable Energy Bonds and Qualified Energy Conservation Bonds. It is of high importance to notice that these financial resource will be taken away from the public administration, while employed into the reserve. Also, through this tool, a part of the risk associated with possible bond' failure is passed on the citizens.
- *On-bill financing:* One of the main factors to take into account when planning a smart city is that often the main obstacle to the deployment of a new technology or infrastructure is the citizens, who resist change and also show little support for solutions that they know little about, and require high investment and economic resources, which are very often lacking or insufficient. In these cases, on-bill financing can be a very useful tool. It allows the local public authority to choose the best set of improvements to make and ultimately finance. In return, citizens will pay a small surcharge on their monthly energy bill to cover the costs of the improvement. It is important in this case to communicate effectively with

the customers, so that they will have a clear idea of the options available. This is very important because not all the infrastructures of a municipality can implement all the solutions available.

- *Value Capture:* this practice consists in the identification and retention of the augmented value that results form a specific investment made by public entities into innovative infrastructures. Guided by the principle that those who obtain certain benefits must pay for them, public administrations have often resorted to such instruments to finance the redevelopment of run-down areas of the city, for which private funding would have presented a higher risk of failure. Through the use of these particular tools, such as special taxes and community improvement fees, it is possible now for the governments to extract a part of the value that should go to the private firms. An example may clarify this concept. An upgrade into the public transit and transport system would translate into a benefit for the neighbours. This benefit will have the form of an increased land value for the citizens and bigger customers' flow for private firms. Considering that these benefits are generated thanks to the new transportation system, both actors should pay in order to achieve the aforementioned benefits, for example, through a public transport impact fee or a land taxation, based on the new, higher value.
- *Tax Increment financing:* this tool is a forecasting-based method. In fact, it is based on financing debt today, anticipating that, in the future, the public government will be able to pay this debt through the future tax revenues. The underlying idea is that, with this method, the cities can start innovative projects today, with the promise of a future payment and especially without the necessity to wait until the public finances will have enough resources to initiate the project. For the public authorities, TIF-based projects are a desirable decision because the buzz generated by the development can generate an increase in property values and thus this aspect makes it particularly suitable for smart infrastructures projects. Moreover, this tool doesn't cost anything to the citizen (at least today), who, against a zero expense, will spectate to higher investments and more intense economic activity. When the project is completed, it will be repaid through the exaction of higher taxes, that are tailored according to the new economic profile of the area affected by the project.
- *Philanthropic opportunities:* a widespread trend of the last year is represented by local and global philanthropic organizations that are willing to participate more and more to

smart projects, at all levels. These foundations are creating funding pools in which every smart city' actor (from the public government to the single citizen) can propose its idea and compete with the others in order to receive a financial help. Public entities should be part of this competition, because the funds provided by these philanthropic parties can cover a great share of the total costs, thus making them an actual financing option that can be used. However, they must consider also that the field of application of this 'race' can be very narrow, thus making the opportunity way less attractive, if it is not aligned with the objectives of the public party.

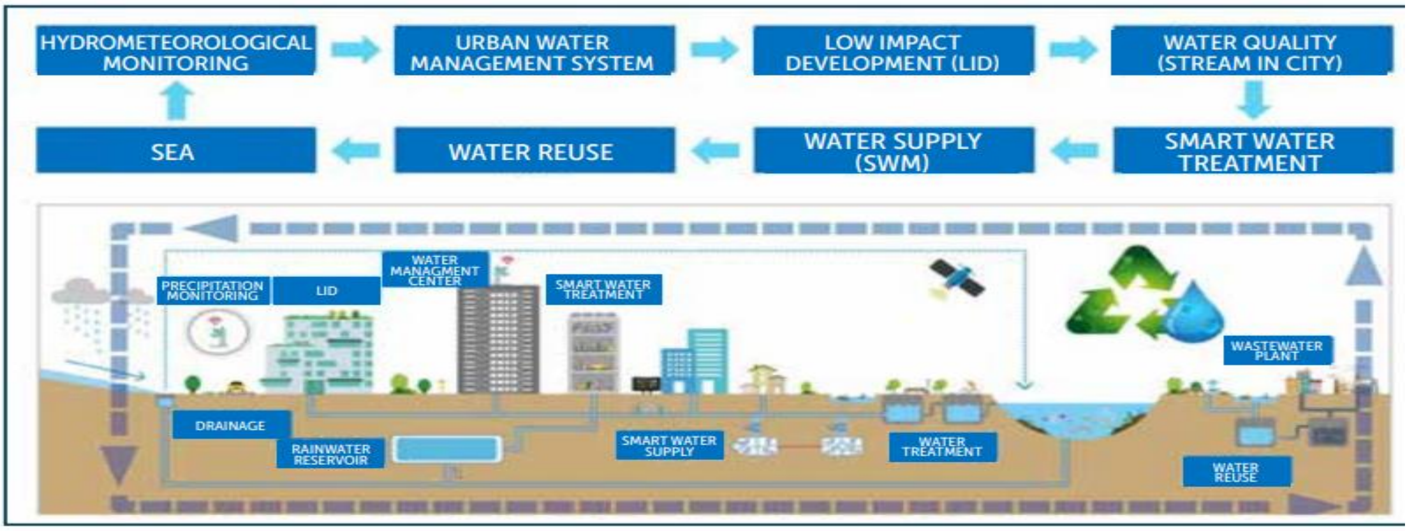
- *International non-governmental organizations:* in this group we can find all the non-profit organizations that are independent from both the private and the public sector. Examples in this sense are sustainability and climate change-focused organizations. These groups provide economic resource in order to fund a very wide range of sustainable practices and their operating area is very big too: it is possible to find them both in highly developed metropolis as well as into underdeveloped small cities. Furthermore, some of these NGOs are also providing technical expertise to the municipalities so that the implementation of more sustainable practices does not clash with the local customs and cultures.[10]

CHAPTER 2

In this section, we will move our focus from the generic analysis of smart and sustainable projects to focus instead on a particular application of the aforementioned concepts: the smart water city. In particular, throughout the chapter, it will be presented a definition of the term and what are the main characteristics of this particular setup. Also, it will be presented a roadmap, through which it is possible to see the step-by-step process that is required for a urban conglomerate in order to turn into a water smart city. Finally, we will analyze all the possible barriers and limitations that may hinder or impede the adoption and implementation of such projects.

The starting point of our analysis begins with the definition of water cycle and urban water cycle and how these two concepts interact with each other. One of the most important functions performed by the water is called 'water cycle'. By this term we refer to the movement of water that occurs within the natural system under consideration. Thanks to the possibility of changing state and thanks to particular chemical-physical processes (such as evaporation, precipitation and condensation), water is able to create a circular process within the environment. it is very important to be able to preserve this cycle, because if you alter even just one of the phases through which you must pass, you risk interrupting or profoundly altering this circular process, with the risk of creating enormous damage to the surrounding natural heritage. Additionally, water plays many other relevant functions at each stage of the process for the surrounding natural environment. As an example, it regulates the environment' temperature, it shapes the physical features of a certain territory

Figure 8. The Urban Water Cycle



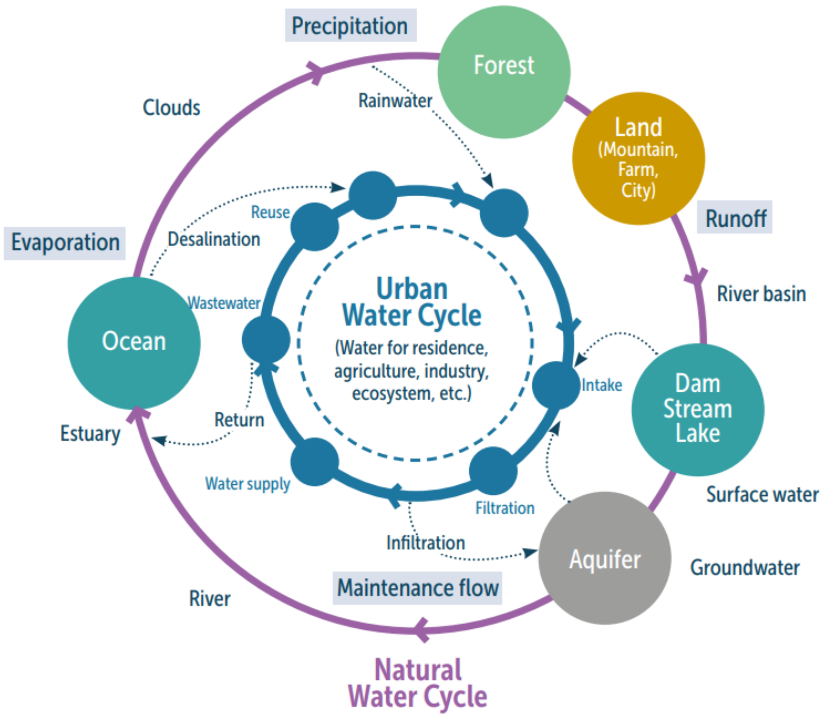
and, more generally, allows local fauna and flora to survive. Thus, protecting this cycle is required also to protect and ensure the sustainable development of all local animal and plant species.

The gradually more invasive activities performed by the human activity, has severely altered the equilibrium of this cycle. Productive operations, such as agriculture, deforestation and desalination deeply modified the way in which water circulates throughout the different stages of the process. For this reason, the scientific literature has coined the term “urban water cycle”, with which we describe the new and modified way of circulation of the water within the environment. The fundamental structure of the cycle remains unaltered: the hydric resources still take part to a circular process, in which the results obtained at the preceding stage influence those that we will witness in the next phase. However, certain important areas have been instead severely influenced by the macroprocesses of human activity, such as industrialization and urbanization. The concept of urban water cycle is presented in the image below, which shows a simplified example of how the water cycle is affected and structurally changed by the human’ activities.

One of the elements that compose the Urban Water Cycle is the stormwater: all the precipitations that fall on buildings, streets and, generally, any object or infrastructure that is composed of concrete cannot be absorbed by the ground but will rather flow away toward the closest waterway available. If we compare this movement with the same phenomenon, but occurring in a natural setting, it is clear that the quantity and speed are substantially higher when we consider the artificial landscape. This, in turn, will cause a higher erosion rate and a higher pollution rate of the water, that will be then collected in the surrounding basins, such as lakes or rivers. Another relevant component of the urban water cycle model is represented by the wastewater. With this term, we refer to all the contaminated water produced by private households and businesses. After the wastewater is flushed away, it is usually transported away toward a reclamation plant, which cleans and sanities it before letting it flow in the surrounding environment. The management of this wastewater and its purification plants is an extremely sensitive and important issue for every municipality. In fact, especially in the poorest countries, the absence of such plants makes it impossible to reintroduce clean water into the local water system, often with catastrophic consequences for both nature and man. Examples of problems that can arise are the possibility of catching diseases if one drinks the water, or significant damage to farmers who use these resources to irrigate their crops. A third component of the cycle is composed by the groundwater. With this term, we refer to all the practices through which we extract water from deep under the ground that will be transported toward citizens' households or will be employed for private businesses' reasons. In order to be considered a reliable source of water, the underlying aquifers must possess the characteristics of porosity (i.e. that there is sufficient space for water) and permeability (i.e. that there is the possibility of movement underground). These aquifers are very vulnerable to pollution: the more permeable the soil, the easier it is for waste discharge to pollute its fundamental values, with possible consequences on a very large scale. Aquifers often have a geographical coverage that goes far beyond the area where the waste was dumped.[11] An example in this sense, is recognizable in the small town of Lonigno, which is located in the area between Vicenza, Padova and Verona. Here it is possible to find a 700 km^2 aquifer that provides hydric resources to more than 350.000 people. According to the research conducted by the local ARPA, the regional environmental protection agency, the level of perfluoroalkyl substances registered in the water was too high. In particular, it was registered, in the blood of many local interviewees PFAS levels that were eleven times higher than the threshold values. This can cause several health problems ranging from ulcerative colitis or thyroid complications to far more serious conditions such as kidney and testicle tumours.[12]

It is now clear why a deep understanding of the functionalities provided by the water, along with a study of both the water cycle and the urban water cycle and their interactions, is seen as a building block in order to build and run a Water Smart City. The dynamic equilibrium between the two cycles gets even more importance if we consider that they, in turn, interact and generate side effects (usually called externalities) which are important for the surrounding natural environment, like forests and lands, oceans and lakes. It thus may be encouraged toward a sustainable development or, on the contrary, severely weakened and put in a dangerous situation. In particular, it is necessary to study what are the effects of hydric resources at each stage of the water cycle, what effects does the urban water cycle cause to the amount and quality of hydric resources available, and how these two processes interact with each other and how each specific dimension of the cycles is affected. For this reason, it is necessary to draw a graphic that can simplify our understanding of the process, in order to optimize and reconcile the two cycles, so that both can be managed effectively and at the same time enable the sustainable development of the local natural environment. The graphic presented below shows how these cycles interact and are interconnected with each other, along with the relevant natural dimensions that come into play at each specific stage.

Figure 9. The Natural and Urban Water Cycles



2.1. Definition of a SWC (Smart Water City)

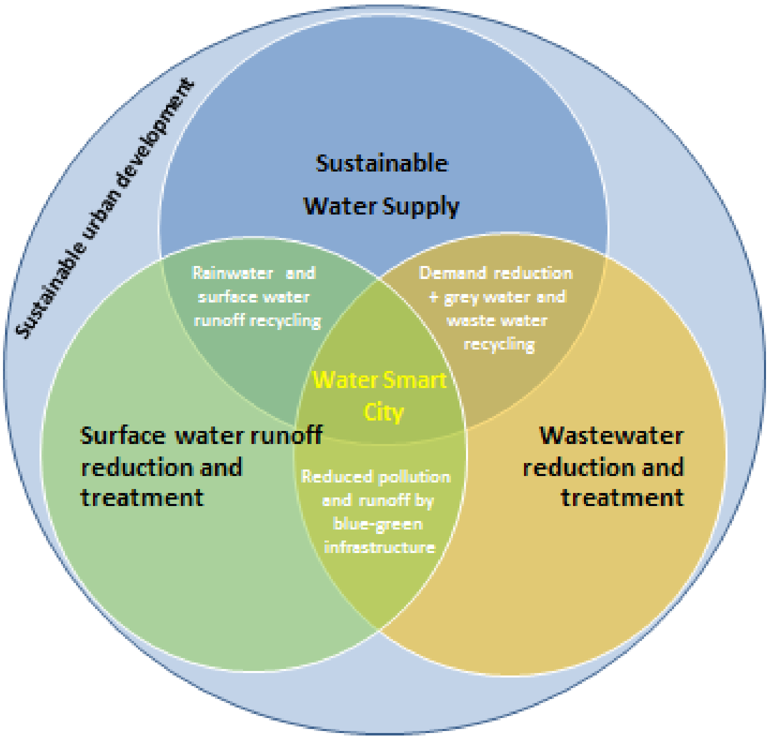
A vast majority of the cities around the world are projected to drain rainwater and sewages (coming both from our households as organic waste and from the nearby firms under the form of polluted water, also known as 'waste water') outside the city's boundaries, while they need supplying water resources from the bodies of water closest to the urban conglomeration, often present in the form of rivers or lakes. However, we have to keep in mind the intrinsic value of a resource such as water stocks, that has to be carefully managed so that eventual resources' wastes are reduced. We can exemplify what has just been said to clarify the concept: it is enough to imagine how many precious water resources are lost and/or wasted when a pipe breaks, releasing hundreds of litres of water into the external environment, which is not recovered or reused for other needs, but simply leaks into the aquifer below. An effective and efficient city system in this sense must not only minimise the probability of occurrence of such incidents or ruptures, but also have a strategy to deal with them, to ensure that water resources are not wasted, but instead redirected to those functional areas of the city that need them (such as, for example, industrial production facilities or rural areas dedicated to agriculture). For these reasons, cities should be considered as catchments, and they should be integrated into the water cycle, as one of its four phases (remember they are: precipitation, collection, evaporation and condensation). In fact, human activity on these resources, especially that concentrated in urban agglomerations, necessarily influences both the quantity and quality of water supplies that are 'passed on' to the next phase of the cycle. In this way, we are now able to attribute direct responsibility to our actions, which have an impact both on the quantity of water (often reduced due to waste or inefficiency) and on its quality (often reintroduced into the environment corrupted or polluted, a phenomenon which, in the medium to long term, negatively affects the quality of life of the urban centre itself). Thus, by considering all types of water as a valuable resources, good practices can arise. In turn, they can trigger a series of effects: the direct ones regard the capability to preserving the freshwater resource and reaching the climate resilience, while the indirect effects deal with the possibility to increase the level of the city's liveability, thanks to the connection between the renewed water infrastructure and the aesthetical and recreational needs of the urban population.

Before continuing in this section, some words of caution are needed. Unfortunately, until these days, a unified and unambiguous definition of what a Water Smart City does not exist. We will thus suggest our own definition of the concept, on the basis of the considerations and concepts just set out in chapter one, bearing in mind that, given the particularities of each city, a single definition encompassing all water smart cities is almost impossible. However, we will still try to articulate the concept, so that even projects that only partially possess these characteristics can define a roadmap for becoming a proper Water Smart City.

According to the paper “Toward Water Smart Cities” (van Hattum et al.), a Water Smart City “integrates urban planning practices and sustainable urban water cycle practices, which generate both direct and indirect effects that are beneficial for the urban setup and for its citizens”. We will now complete this definition by presenting the three main pillars that represent the fundamental basis that is necessary for a urban centre in order to transition to a Water Smart City:

1. **Wastewater reduction and treatment:** we can list in this category all the practices oriented toward a sustainable water demand reduction from citizens and private firms. Examples in this sense are represented by the possibility to reduce water usage by installing water meters in homes and private companies, with the possibility to obtain a tax benefit or a tax burden, depending on whether the considered subject has exceeded some average annual reference values or not. In this category we can find also all the practices through which we can simplify and encourage the water recycling, in particular regarding the grey waters (which are all domestic wastewater generated in households or offices without fecal contamination)
2. **Sustainable water supply:** we are referring here to all the systems, infrastructures and practices that allow to collect and re-utilize hydric resources coming from precipitations and surface water runoffs. An example in this sense is offered by Aquality, a British company that offer systems for intelligent water management. Among the tools, there is Aqua Storm Control (ASC), which combines the IoT technology with the CMAC one (Continuous Monitoring and Adaptive Control) in order to monitor and reduce the impact of floodings and pollution on a site or catchment scale.
3. **Surface water runoff reduction and treatment:** we will include within this category all the infrastructures that can help a municipality in reducing both water pollution and runoff. Green and blue infrastructures are defined by the European Commission as “a strategically planned network of natural and semi-natural areas with other environmental features designed and managed to deliver a wide range of ecosystem services such as water purification, air quality, space for recreation and climate mitigation and adaptation. This network of green (land) and blue (water) spaces can improve environmental conditions and therefore citizens' health and quality of life”

Below it is possible to find an image explaining the three dimensions just discussed. It is important to notice that each dimension influence the others, so a call for a coordination between each dimension (and between each individual acting within those dimensions) is required in order to achieve superior and widespread benefits.[13]



2.2 Water Smart City approach

An important aspect that may be overlooked is related to the particular approach and mindset that we have to possess when projecting, designing and implementing smart water-related solutions. The Water Smart city approach has been presented for the first time by Wong and Brown in 2009. It is based on three pillars that will form our conceptual layer underlying the water-sensitive city and they are necessary drivers in order to operationalize the approach and thus obtaining tangible results. It is interesting to notice that the concepts that are embodied within these three principles have been already studied and analyzed by the past literature, but it is only in Wong and Brown's 2009 paper, "The water sensitive city: principles for practice", that these concepts are combined together in order to design a clear track that can radically alter urban water management practices. In a water efficient city, each principle would be integrated into the urban scenario thanks to urban planning and designing techniques. We have also to keep in mind that, since this concept was developed for the first time, many efforts were made in order to operationalize it into urban conglomerates that, for obvious reasons, present very different economic, social and institutional features. Therefore, a summary of the knowledge gained through the application of these principles will be presented. The idea here is not to define monolithic and irreversible concepts nor to provide a guide that must be universally utilized; it is impossible to do so, considering that each city, even those in the same state, has particular features that makes its urban water transition totally peculiar. Instead, the idea is to understand and discern what we have learned during these years through practical applications of the concept. In this way, we can identify a path that must be followed by the researchers in order to deepen our knowledge on the subject, but also to make diffuse and widespread water smart cities approaches. Additionally, it is also possible to leverage the past experience in order to sustain the expansion of a water-sensitive agenda to a broader sustainable city and SDG agenda.

The first principle is: "**Cities as Water Supply Catchments**". It requires that cities have diverse water resources that are distributed into the system thanks to a well-integrated and well-manged infrastructure that, at the different levels of the municipality, are either centralized or decentralized. A city oriented toward wise water management has a supply strategy that requires the exploitation of multiple water sources, along with a deep integration of the various infrastructures that are required for harvesting, treatment, storage and delivery. Moreover, this set of tools that will be utilized should also bring with itself the minimum amount of costs possible: we are referring here not only to the possibility to reduce the costs related with the installation of new equipment or the costs related with the maintenance of the existing infrastructure, but also to a series of direct and indirect costs that are produced by the environmental impact of such infrastructure and other typologies of externality. It is possible to find, among the alternative water sources, examples such as managed aquifer recharge schemes (groundwater), urban stormwater (catchment runoff), recycled wastewater and desalinated water. It is possible to find the majority of this tools inside the city's limits and we can distinguish them basing on the level of reliability, environmental risk and cost basis. A practical example of the application of this principle is detectable in Australia. After one of the biggest drought that has ever been registered, in a period that has been renamed the Millennium Drought, a state-wide process of transformation and transition in order to become water sensitive. Therefore, the government considered necessary the design and implementation of water-management instruments. In particular, the cities that were closer to the sea adopted in a short period of time seawater desalination plants, that allowed them to obtain a new and differentiated water source. The effort and the resources invested to stimulate this initial change triggered a further series of changes, which have been proposed by successive governments. In particular, they tried to pursue more sustainable and cost-efficient alternatives that required more time to be implemented and developed, often resulting in cascade effects and positive externalities that go far beyond what was initially planned. We can find many examples in this area, such as stormwater harvesting, wastewater recycling, fit-for-purpose treatment and use of water, and demand management. The Victoria State Government exploited the "safety net" provided by its desalination plant to implement other typologies of hydric sources. The objective was to avoid the construction of another desalinization facility that should have coped with the raising population of Melbourne. Another indirect effect generated by the application of this principle is that often the pursuit of different sources of hydric resources results in the implementation of infrastructures that will perform several differentiated function. As an example, the stormwater-harvesting projects using nature-based solutions produced a major impact on the design of the city, that is now strongly influenced by the application of such principles. In fact, out of this process emerged a movement called WSUD (Water Sensitive Urban Design) that is now a very common and widespread practice in many Australian municipalities. Another important example is represented by the Star City project in Korea, Seoul. Here the rainwater harvesting infrastructure has been combined with real-time instruments that are capable of forecasting storms and control technology solutions that help alleviate urban floodings. It is interesting to notice that the solutions adopted by the municipality generated remarkable results: it has been registered an average annual saving of 26.000m^3 of water, along with a significant reduction in energy consumption (8.9 MWh) that was previously related with the activities of transferring water from an external catchment. Additionally, we can consider also other externalities that has been produced by this innovative infrastructure: the downstream drainage system, that was previously designed for a 10-year Average Recurrence Interval

(ARI) storm, has seen its levels of service increased to a 50-year ARI, without the necessity to adopt any specific upgrade.

Cities providing Ecosystems Services is the second principle presented by Wong and Brown. Here, the fundamental concept revolves around the integration of urban landscape design with sustainable urban water management. Such integration will ultimately result in providing superior ecological functions on the one hand, while on the other hand guaranteeing a certain level of services within urban spaces. Thanks to the adoption of such principle, the objective is to reduce or minimize the impact of environmental changes on urban surfaces, while simultaneously increasing the stock of natural capital that is possible to find both within the city boundaries and the nearby areas. In fact, landscapes are the end result generated by the meeting of natural forces and human-induced ones, that, in turn, interact with each other inside a regional and global ecosystem. Therefore, public open spaces in water-sensitive cities perform multiple roles: on one side, they improve the existing amenities while, on the other, provide ecosystem services that will help both the artificial and the natural environment. In order for the urban design to achieve ecosystem services, we have to deepen and possibly modify our traditional knowledge about the concepts of 'open spaces' and 'landscape features'. We need in fact to realize their 'ecological functioning' feature that is necessary in order to deliver sustainable water management, to influence the urban microclimate, to facilitate carbon skins and also support an improved and more efficient urban food production. Such peculiar landscapes are also called with the name of "nature-based solutions", whose main feature is represented by the imitation of natural processes to support natural processes as well as human' ones. This practice also shares many features in common with a practice called 'Blue Economy', which develops and deepens the concepts of green economy theory. Similar to 'nature-based solutions', the blue economy is based on the development of physical principles, using scientific techniques such as biomimesis, a still little-known field that is based on the study and imitation of the characteristics of living species in order to find new production techniques and improve existing ones.

The importance and relevance of such practices is apparent if we consider that the International Union for Conservation of Nature explicitly encouraged a change of approach from traditional water management to a mix of green and grey investments, considering that nature-based solution may play a major role in helping us achieving the 2030 Agenda for Sustainable Development. These practices have also been invoked in 2019 UN' Secretary general's Climate Summit that took place in New York and in several COP25 meetings. Cities that represent the best-in-class example of environmental sustainability are now starting to develop a common vision statement, that reflects an urban community with increasing understanding of the role played by nature-based solutions at each scale considered. If we go beyond urban boundaries and take into consideration large regions, such solutions can preserve and restore natural ecosystems like, for example, efforts directed toward the protection of wetland and coastal mangrove systems. If instead we zoom in and consider the local scale, the encounter between public space/landscape designs and biomimicry can unlock superior ecosystem service outcomes, such as flood management, urban waterway renaturalization, stormwater quality improvement, urban cooling and general urban area revitalization.

The third and last principle is defined as follows: **Cities comprising Water-sensitive Communities**. According to this principle, a key role is played by the community's values and aspirations, that should make a contribution, such as to influence, on one side, the decisions regarding the urban design and layout and, on the other, all the practices related to the management of urban water resources. This aspect gains even more importance if we consider the possibility to agree with the citizens how to plan the future urban development process, so that it is possible to avoid oppositions and resistances, that may emerge in communities particularly attached to their natural heritage. These may cause an increase in the time required to complete the works, with a consequent increase in the level of costs incurred. In line with this thinking, a water smart city has at its base a stock of social and institutional capital, which has multiple dimensions:

- A group of communities that have an environmentally sustainable lifestyle and that recognize the dynamic and unstable equilibirum that exists between consuming and preserving the urban natural heritage.
- A group of dynamic industries, guided by skilled and proactive entrepreneurs, that have to be able to stimulate and adapt to an innovation process, whose benefits can go beyond the limits and the boundaries of the economic sector in which they operate.

- A strongly innovation-oriented set of policies, that are able to stimulate and facilitate the dynamic process of urban transition towards a water smart city

In this context, an interesting example is provided by the analysis of the socio-technical drivers that played a decisive role in the adoption of various WSUD infrastructures. it was found that a complex network of interactions and synergies between the change agents involved in the process and a set of pre-existing enabling context variables are crucial for the transition process to be successful. Relevant variables include: the level of socio-political capital required to protect and secure water resources, the presence of opportunities to obtain alternative financing methods, and the number of institutions and bridging organisations that are established to facilitate and encourage the coming together of business and science. When the interrelationship between all these factors is successful, a series of positive cascading effects are generated, such as: simplifying the formalisation of objectives to improve stormwater quality, encouraging the adoption of WSUD infrastructures by an increasing portion of the market, and facilitating the process of innovation and development of capacity building tools. Within this set of tools, all techniques related to the development of future water management scenarios, water quality modelling software and innovative and engaging guidelines, capable of engaging an ever larger portion of urban stakeholders, are included. Continuing in the wake of the example provided by Australian cities going through this transition, special attention has also been paid to the application of the third principle. One example of this is the increasing integration between the various water services (supply, sewerage, drainage and flood management) and the increasingly intricate relationship between urban planning & design and the water infrastructure planning and implementation process. Not only that, many local governments have adopted policies and initiatives geared towards the preservation of urban water resources, such as the Cooperative Research Centre for Water Sensitive Cities, an organisation funded with AU$120M that brings together the worlds of research and industry. Thanks to this initiative, some interesting ideas have been developed, such as a method to show what would be the 'optimal portfolio' of water supply options or the promotion of government reforms at both local and state levels that reflect and respect the results of previous research.14

In light of the analysis just conducted, it is therefore possible to reframe the definition of water smart cities provided at the beginning of this chapter, to integrate it with the principles just presented and analysed. However, it must be borne in mind that it is impossible to propose a single model that fits all of the cities involved: it is often possible to find multiple differences from a geographic, socio-economic, political and institutional point of view, even between cities in the same state and/or not very distant from one another. For this reason, it is deemed necessary to formulate a universal and flexible definition, which allows us to distinguish which cities are making an urban transition to a water smart city and which are not, and which can be applied to the most diverse urban contexts. This is done with the aim of creating a common meeting territory in which all municipalities that decide to undertake this transition process can meet and can generate synergies through the mutual exchange of resources and knowledge. Through the creation of "communities" of water smart cities, it is in fact possible to exploit the benefits offered by network and knowledge economies of scale. Taking up therefore what was stated at the beginning of the chapter, a Water Smart City can be defined as *"a city which integrates urban planning practices and sustainable urban water cycle practices, which generate both direct and indirect effects that are beneficial for the urban setup and for its citizens. Those effects are achieved through the implementation of three operational pillars: 1) Wastewater reduction and treatment 2) Sustainable water supply 3) Surface water runoff reduction and treatment. These operations should be carried out in compliance with three fundamental core ideological principles, which are: 1) Cities as Water Supply Catchments 2) Cities providing Ecosystems Services 3) Cities comprising Water-sensitive Communities."*

2.3 The transformation process toward a Water Smart City

In this section, we will present the process that brings a city to become progressively a water-sensitive city. The objective is to be able to create a theoretical roadmap that allows to the municipalities to understand what path they have to follow in order to achieve superior urban water management practices. Moreover, this toll can be useful also for all those municipalities that already started their transition process to understand at what stage they actually are and what actions has to be done in order for the transformation to be successful.

Before presenting the framework, it is necessary to focus on an important theoretical concept, called New Institutionalism. It will be utilized as our theoretical cornerstone upon which the entire framework is based. It is defined as “an active field of research, concerned with understanding the processes involved in institutional change”. Usually, we are used to divide the institutions between ‘hard’ and ‘soft’ ones. Hard institutions are represented by all the formal organizational structures, the departments, along with all the set of laws, taxes and subsidies. Typical examples of soft institutions instead are social relations, informal networks, professional cultures and social worlds. Moreover, we have to keep in mind that, according to what stated by Scott, we usually identify three mutually reinforcing pillars, whose collective and mutual interactions will determine ultimately how the citizens can benefit from them. Thus, analyzing how these dimension can change through time is necessary for us to understand how to manage successfully the transformation process toward a Water Smart City.

The first pillar is the *Cognitive* one, we usually include within this category the level of knowledge, dominant thinking and skills that are possessed by a particular organization. If we consider the water infrastructures, it is possible to notice a shift in the cognition' dimension if we consider the growing dialogue and scientific attention that has been posed toward WSUD infrastructures that, in turn, pose a threat toward the traditional, widespread water management practices. The second aspect is represented by the *Normative* dimension, within which we can find two articulations of the concepts, represented by the values and the leadership that are expressed and recognizable within a specific organization. an example of a shift in the normative parameters of institutions is the change in underlying values that, thanks to the introduction of urban sustainability practices, are convincing more and more institutions to embrace environmentally oriented ideals. The third dimension is the *Regulative* one, which, in turn, is composed by the administration, along with the rules and systems that are necessary for such administration to be effective and efficient. Within this dimension of analysis, it is possible to notice a gradual shift toward environmental protection practices', that is represented by the implementation of laws and rules, whose ultimate goal is to protect endangered natural environments and urban water resources. Within this context, the main idea underlying New Institutionalism is that the distinguishing feature of the institutions is their ability to encourage or, conversely, to pose an obstacle to significant internal changes, that take place in a short timespan. In order for a transformation process to be effective, it is required a mutually reinforcing change within each of the three aforementioned pillars, that have to be transformed together in order to maintain reciprocal coherence between each other. Unfortunately, we have to notify that change efforts oriented toward a widespread diffusion of WSUD infrastructures often influence only one of the three dimensions. By way of example, changes have often been proposed that are exclusively geared towards educational programmes that have a major impact on the cognitive dimension of institutions. however, the lack of complementary measures aimed at changing the way people value water resources more or less (normative pillar) or aimed at modifying existing laws to encourage more sustainable practices (regulative pillar), means that the effort is incomplete and some of the achievable results are left on the table. Another example is represented by regulation shifts that are not accompanied by sufficient efforts for transforming the community's thinking (cognitive pillar) nor values (normative pillar). These transformational efforts are often doomed, because they lack the fundamental supportive function that is obtained through the synergy of the three pillars working together. A change in the community's mental schemas and values is often the starting point necessary to trigger regulation shifts. Yet, norms and laws are usually determined by those stakeholders with the highest institutional power, that may be oblivious of the need for alignment of visions between institutions and citizens. Therefore, the New Institutionalism framework helps us understand the transformation process presented below. The analysis is presented in the "Water, science and technology" magazine and we will use Australian' municipalities as a recurring and clarifying example. In particular, we will try to assess the institutionalization efforts of SWUM infrastructures. To do so, it is required a deep study and localization of the moments in which specific changes in urban water technology and management practices have occurred. According to the past research conducted by Brown & Farrelly (2007), it is possible to identify a set of institutional barriers and obstacles that pose a threat to SWUM adoption and diffusion. This means that there is a high probability that the cognitive, normative and regulative dimensions are not aligned with each other with the goal of spreading SWUM constructions, but rather they are still rooted to the past institutional values.

The method that has been used in order to create this framework is characterized by three research phases. In the first one, the authors put emphasis on the analysis of the past practices. The dominant question that led the research was: “What have been the major cognitive, normative and regulative developments in Australian urban water management history since the early 1800s?”. The development patterns of hydric resources management of the four biggest Australian cities (Sydney, Melbourne, Brisbane and Perth) have been analyzed until the 21st century. Along with the analysis of historical scientific literature on the thematic, further examinations were conducted, particularly those regarding former and actual laws and policies. Additional media documentation has been carried out, together with field inspections of historical infrastructures that, in the past, has been used for water management’ practices. A large pool of data was then created, so that the researchers could study and compare the results, in order to see if the case studies considered showed some degree of coherence between each other’s or if, on the opposite, some incongruences have been emerged. The second phase of research directed its attention toward the identification of all the possible obstacles and facilitators of progressing sustainable urban water management practices that were in place at that time. Here, here, an assessment of the current state of the art of water management practices is proposed. It appeared immediately clear that the main issue was that the adoption rate of the municipalities remained pretty low, even if there was the possibility to benefit from the use of innovative technologies. If we consider this problem through the New Institutionalism approach, it seems that a shift in the cognitive dimension took place, but insufficient efforts were put to stimulate a normative and regulative transformation. Considering that a primary role is played by the public entities in order to foster sustainable urban development processes, the researchers investigated what could represent an institutional barrier or driver that could support the transition. In particular, three cities were analyzed: Melbourne, Perth and Brisbane. They were selected because each one of them possessed a peculiar institutional structure, so researchers could understand which set-up would perform better, why and whether it could also be reproduced in other public governments. Thanks to this multiple sources of on-field information, it was also possible to look for possible converging or contradictory evidence. A major portion of data was gathered by conducting interviews with urban water professionals, regulators and consultants that acted on behalf of the local and the statal governments. In the last phase of the investigation, the attention was directed toward the future possible scenarios. Here the main objective was being able to model and forecast what will be like the future scenarios, how effective the reform has been, what results can be achieved and what practices should be encouraged to achieve them. The effort was directed, in this case, towards an analysis of the future socio-technical factors that will be needed to support sustainable practices in water resource management. It is important to notice that, after each phase was concluded, a wide group of stakeholders, among which we find members of regional councils, key NGOs partners and state officers, was interviewed to assess and grant both internal and external validation of the data collected. It is also interesting to appreciate that, despite this study was conducted only among Australian cities, the authors believe that this concept may be easily adopted also in the European continent.[15]

Thanks to the research efforts, it has been possible to identify six stages through which a city must pass in order to ultimately become a Water Smart City. It will therefore be presented the framework, which is composed of a series of states that the municipalities have to pass through before being considered a water sensitive city. As we can see, for each transformation phase, two dimensions will be considered, together with their evolution during the process: cumulative socio-political drivers and service delivery functions. The former represents changes in norms and regulation that are required at each specific phase in order to progress to the successive, while the latter represents the ultimate functionality goal that has to be reached at each transformation stage. Moreover, each transformation state is characterized by a peculiar change in one of the New Institutionalism' three pillars presented above. It is also important to understand that the presented scheme is intended as a dynamic continuum, in which the hydro-social equilibrium reached in a particular moment will influence the equilibrium in the following states. As one progresses with the transformation process, the complexity of the practices and goals to be achieved increases. Furthermore, Although the authors' idea is one of continuous progress, it is also possible to encounter cities that, on the contrary, regress and return to primitive 'evolutionary stages'. Similarly, it is not necessary to go through each stage to reach the final goal: the possibilities offered by synergies and economies of scale and knowledge may allow one or more stages of the development process to be skipped.

1. **Water Supply City:** the first stage of the model is represented by the ancient first urban water city in Australia that were founded immediately after the arrival of the Europeans. The legal base was directed toward the provision of safe water for an increasing amount of population. The elites were the social class that was guaranteed the greatest amount of water resources. The vast majority of knowledge and cognitive capital was imported from UK. they guided the construction and management of a centralised water supply system, in which huge infrastructural pipes were built and were in charge of extracting water resources and moving them to the city. In the moment in which a minimum level of supply was reached, a new wave of reforms imposed the recognition of water as a public good, that should have been provided by the government to all the members of the society, so that also the poorest part of the population could benefit from it. Through the instauration of a centralized taxing system, that would have covered the costs for water infrastructures and supply, the first formal hydro-social contract between a government and its citizens was born. Usually, the taxation took the form of flat property rate or of specific water tax. Another collateral feature of this social contract was that it implied the delivery of huge stocks of hydric resources to an increasing urban population.
2. **Sewered City:** the second stage was reached between mid and late nineteen century. At this point, it is possible to assist to the formation of cognitive linkings between UK and Australia, that allowed the two country to enter a continuous communication and exchange of information. The main concern on the European side, at that time, regarded public health concern. Specifically, it was discovered that people could catch a disease because of the presence of pathogens in the water supply, because of waste generated by citizens, industrial waste and sewages. This caused the adoption of sewerage systems, that could transport dirty and infected water outside the urban space. The new approach triggered a cognitive change also in Australia that started to imitate the English relatives. However, soon it was clear that the same infrastructure was impossible to reproduce, due to the elevated high costs, so many cities directed its efforts toward separate sewerage systems, which often took the form of on-site septic system. Additional contributions from the citizens became then necessary to support the evolution of the network. In this case, the contract

consisted of a promise from the public authorities to grant a minimum level of public health protection, through the implementation and use of sewerages, in exchange of a raising a levy in addition

3. **Drained City:** these peculiar phase was reached after the end of WWII, in a period characterized by diffused practices of raising public investments in order to reach welfare goals. Thanks to the adoption of new transportation systems, such as the cars, people started to move away from the cities to go in more isolated areas. The result was that flooding and property damage rapidly raised. Therefore, a stock of local knowledge was created through the use of local rainfall records and drainage design standards. Moreover, in this period Australia establishes itself as one of the most dynamic and study-oriented countries for sustainable urban hydrology practices. The aim was to generate models that would allow stormwater to be moved out of urban areas and redirected to the rural areas that needed it most. This deeply affected the development of many Australian cities, with the implementation of underground waterways and channelled rivers in order to consent the construction of houses also in areas exposed to hydrogeological risk. The agreement between government and citizens consisted of granting a security service that could support the rapid growth of urban areas. Over time, these services are guaranteed by both central and, gradually, also local governments
4. **Waterways City:** for each stage of the model presented, the social contract that has been explicitly or implicitly signed was gradually expanded, with the public authorities offering a deeper and more complicated set of services in accordance with population growth and city management issues that were arising. However, the Waterways City interrupts this progression by analyzing and modifying the service delivery functions previously implemented. According to the past practices, it was common practice for the public authority not to link the provision of a natural-based service to an increase in the level of taxes paid by citizens. This happened because there was the widespread idea that the environment is benign and deserves much less attention than the economic sector. Yet, thanks to the emergence of protest movements between the ‘60s and ‘70s, a new vision of environmental issues had to be developed. What was indicated as particularly worrying for the communities were the conditions of the waterways’ infrastructure in which a high level of degradation

was founded, due to gross pollutants and hydrocarbons, algal blooms and beach closures. Another pressing issue at that time was represented by the urban communities, which grew significantly in the past decades, and that now asked for an increased level of amenities and green spaces within the city's boundaries. For these reasons, the public authorities shifted their approach, and started integrating it into their planning and decisional process. This allowed to recognize that hydric resources can embody recreational features that can be leveraged to deliver leisure services to the citizens. Additionally, significative initiatives were launched in order to clean waterways from polluting elements. This was done through the reduction of waste created by the wastewater treatment plants and productive, industrial processes while also implementing centralized sewerage networks. The problems originated by a polluted waterways, has sparked a new wave of research, that started new technological solutions, such as wetlands and bio-filtration systems, to tackle this issue. It is important to notice that a major role has been played here by the deployment of a series of cognitive tools, such as industry guidelines and capacity building programs, that instructed the economic actors involved in this transformation process about the public agenda. Nevertheless, we have to notice that significant barriers are still present that can hinder stormwater quality management practices: one of the biggest is that neither the former social contract nor the centralized technologies have the required features necessary to tackle and address a diffuse problematic like stormwater pollution. It is thus necessary a shift in the vision of the public policy maker, that has to develop a solution that can be applied in a geographically wide and dispersed area, along with a proper financing mechanism that could support and make such solutions viable. In this context, the complexity is further increased by the presence of new urban stakeholders, like environment protest groups and non-governmental organizations. This resulted in an increasing tension between public and private actors and led to the formation of to opposing groups: those who wanted to stick to the traditional values adopted, and those who were encouraging and calling for a change in urban hydric resources management.

5. **Water Cycle City:** this urban layout was created as a response to all the problems that emerged and were presented in the previous transitional stage. Moreover, it

contains within it the values of multilayer sustainability, which must be not only environmental, but also social and economic, so that practices that follow this current of thought are viable in the medium to long term. The underlying idea here is to try to reduce the tensions that originated in the Waterways City. In this context, scientific research is geared towards ensuring, on the one hand, the conservation of water resources and, on the other hand, the identification and exploitation of diversified water sources. With regard to the latter, the aim is to have access to different sources with different quality levels, which are used in an integrated manner for a multitude of purposes (agricultural sector, private industries or citizens), both locally and globally. All these practices are carried out with an eye on, on the one hand, how much energy is required to enable this and, on the other hand, the protection of the quality of the waterways. Thus all the practices are oriented toward reaching the ultimate goal of hydric supply safety and waterway protection. However, it is important to notice that a threat is posed on the social contract, in particular for what regards the delivery of risk-free water supply services. This happens because, considering that the water cycle is managed simultaneously by the public authority, the citizens and the private sector the risk is divided and spread among all these actors involved. Thus, it seems necessary to find a common meeting ground for each of the parties involved, in which they can discuss, devise and implement solutions capable of meeting such a wide range of needs. in this sense, the authors identify Australia's institutional structure as one of the major obstacles that can complicate the spread of such practices, that go under the name of Total Water Cycle management.

Furthermore, this scenario is made more complicated if we consider the ongoing debate regarding the use of centralized or decentralized handover of recycled hydric resources. This may happen as a result of the fragile social contract of Waterways City, which ties the actions that can be undertaken to the boundaries imposed resource limits. For this reason, it has been registered rise in the use of centralized systems, with an essential return to past forms of the social contract. The main debate that has taken place in this field sees two opposing factions: on the one hand, the supporters of a return to the social contract of the early stages (namely Water Supply City and Sewered City) while, on the other, those who believe that it is necessary to implement solutions aimed at identifying alternative water sources through the exploitation of the potential offered by decentralised technologies, in line with what is preached in the Waterway City section. According to the researchers' point of view, it is possible that Waterways Cities in the medium/long term will reach an equilibrium, allowing the transition to Water Cycle City to begin. In turn, this city structure must guarantee a minimum level of environmental protection, which must be offered together with security services, public water health and flood control, seeking to offer this set of services in an integrated manner.

6. **Water Sensitive City:** this is the final and ideal goal to which the transition progress should bring. At this stage, a multi-dimensional social contract has been signed by the parts. Specifically, it will cover many themes, such as: environmental protection, water supply security, protection from extreme meteorological events, public health, economic sustainability and the provision of amenity services. The values embodied in the policy promoted by the authorities will guide the community under the principles of establishing an intergenerational equity of natural resources and ensuring ecological integrity. This will allow to increase the levels of social capital that, in turn, will induce a switch in the private businesses' mindset to focus on innovative management practices for urban hydric resources. This encounter between the public society and the scientific/economic sector will be reflected throughout the city, with the deployment of large technology stocks and urban infrastructures that will promote widespread environmental welfare. Finally, dynamic and flexible institutions are required as the fundamental building block of the city, so that it is made possible to continually modify and incrementally improve the social contracts, depending on the occurrence of pre-determined external conditions.[15,16]

It is important to notice that the last step of the urban water transition model is imagined by the authors as a future hypothetic scenario. This happens also because, at the time of writing the paper (2008), no tangible examples of a Water Sensitive City still existed. However, we will see through the paper many examples that shows that many municipalities already started to take action and begun their transformation process. This proves that, in more than 10 years since the article was published, many public initiatives were encouraged and it is beginning to show a growing interest in the topic, both because of the increasing frequency of natural disasters and the costs associated with repairing a damaged socio-economic infrastructure network. Another very interesting aspect is the fact that, although it may be feared that the proposed transition model is outdated, it is in fact continually and repeatedly cited within the literature dedicated to Smart Water Cities. This demonstrates that the model proposed by R.R. Brown et al. is inherently robust and therefore remains a valid tool today. Furthermore, it clarifies the main drivers that must be taken into account for the transformation to succeed, as shown in the image below. Finally, the possibilities offered by future scenarios (Water Cycle city and Water Sensitive city) allow us to imagine state-of-the-art solutions in line with the technologies available to us.

It is, of course, clear that this process is far from simple and free of possible contingencies. An enlightened political class is needed to guide public organisations through a process of enrichment of institutional capital. This should also be accompanied, on the one hand, by a dynamic and cutting-edge scientific/economic sector and, on the other hand, by a lively and proactive community that must be prepared to tolerate sacrifices in the name of widespread prosperity. The simultaneous presence of all these elements is obviously very difficult to achieve and, if there is one, to guide and direct towards successfull goals. However, it is the

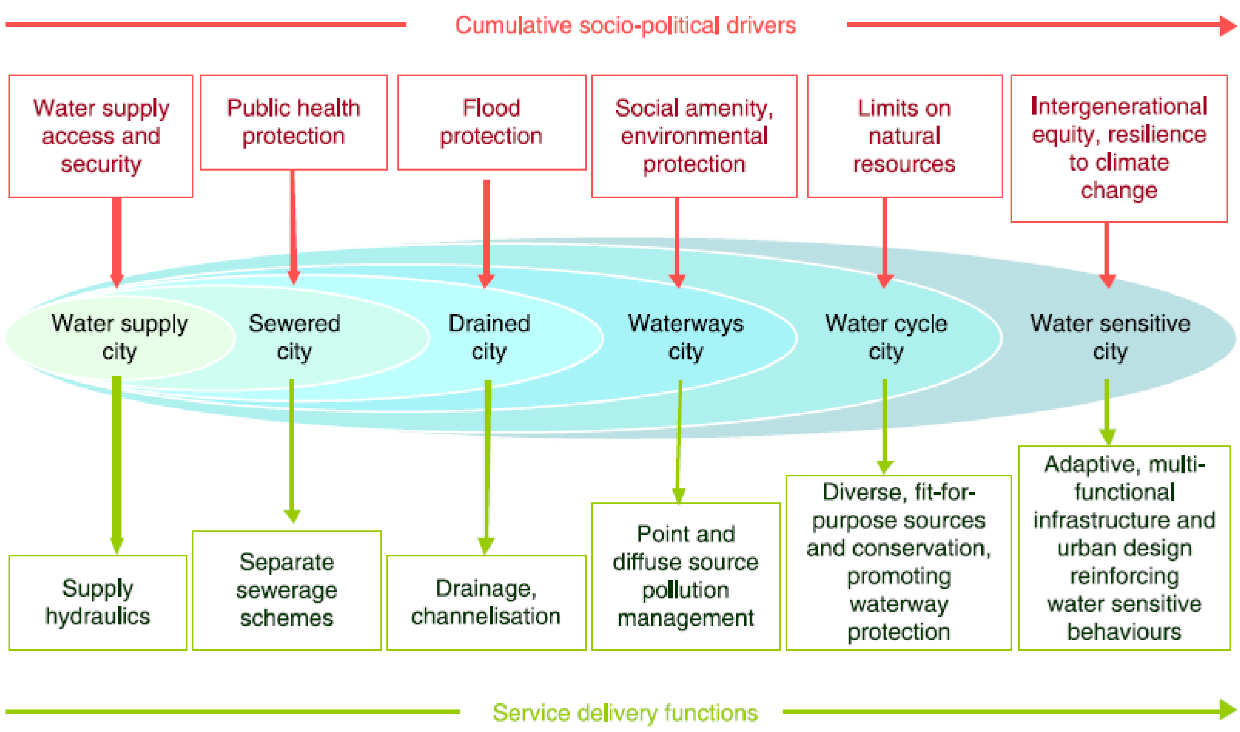


Figure 1 | Urban water management transitions framework.

author's opinion that a gradual interest in the subject (to the point of potentially making it 'mainstream') could largely simplify this process.

2.4 How to operationalise Water Sensitive cities

After the examination and analysis of the most relevant theoretical concepts that are presented above, we are now ready to translate the aforementioned principles into operational guidelines. A word of caution is required here: the framework that will be presented is not intended as a universal solution for all the municipalities. Once again, we have to remember that each city possesses its peculiar characteristics that determine the pace and the probability of success of the transition toward a WSC. Moreover, the local context and the initial conditions of the system, that may be altered by the presence of extreme climatic conditions or elevated levels of waterways' pollution, significantly shape the path that will be taken by a specific city along with the associated results. We are referring here with the term "local context" to all the variables that are specific of a considered system, such as the geo-morphology of the territory, its climatic and biophysical conditions. We will include here also social and institutional factors that may have a role in the transition, such as the openness toward the adoption and implementation of water-oriented practices, technologies and infrastructures and devices. In order to turn theory into practice, we thus need a method that allows to all the relevant actors to assess their initial situation, establish clear and relevant goals and take effective actions that allow to reach them. It will thus be presented the framework exposed in the paper "Transforming Cities through Water-Sensitive Principles and Practices" written by Wong and Rogers. it is characterized by the compresence of four approaches: systemic, interdisciplinary, design and collaborative.

The first method, called Systems Thinking, is an omni-comprehensive approach that encourages the public decision-maker to understand how each component of the system connects with each other and how this relation ultimately forms the fundamental features of the system itself in the medium/long term. To be able to turn theory into reality, it is required the ability to locate, study and leverage the dynamic and multi-dimensional relationships between technological, social and environmental factors that underpin the urban structure. Such holistic view is necessary in order to grant different benefits, that require the cooperation and coordination of multiple interacting mechanisms: let's consider the example of a city that promotes effective policies to reduce the waste of hydric resources. Despite the obvious positive effects that may bring any practice for reducing waste of resources, this kind of good practices may still fail if, for example, the pipe infrastructure is contaminated, thus making water unavailable to citizens and ultimately failing in providing widespread welfare among the population. In the same way, the effectiveness of a water-sensitive structure is measured not only by the amount of rainwater it is able to retain, but also by how well it succeeds in improving biodiversity and urban liveability.

The second element required is Interdisciplinary Thinking, with which we refer to the utilization of different theoretical approaches that can dive deep inside a problem and is able to provide coherent and effective solutions. If we are commanded to build a new infrastructure, for example, knowledge of engineering is a prerequisite, but it is not sufficient: the opinion of a person with the right sociological and political knowledge of the community in which such a plant will be implemented is also needed, in order to understand what the response of citizens will be and to assess whether specific policies are needed for its sustainability in the medium/long term. The same reasoning applies if we consider the aspects related with the design of the project and how does it fit within the surrounding urban and natural environment. All the practices that encourage and stimulate the interconnection between different theoretical schools of thought are extremely beneficial in helping the diffusion of WSUD solutions.

The third view that we have to keep in mind when adopting sustainable practices is called Design Thinking. In our field of study, being able to design and deliver a process requires the development of an integrated solution that must be able to perform complex sustainability tasks. An example in this sense is represented by the CRC research synthesis process, which brings together scientific knowledge with local business' owners in order to create a common platform in which share new ideas and test the most promising ones. Similarly, another example can be found in a programme promoted by Monash University, located not far from Melbourne. It allows students who have just finished their studies to study and propose innovative solutions that can address real-world problems. This examples show that this third approach may bring significant results, but it is necessary to utilize it in conjunction with clearly-defined objectives, a deep understanding of the urban context in which this solution will be implemented and the use of water-sensitive principles that constitute the fundamental element from which decisions are taken. If applied correctly, this practice can facilitate the development and adoption of smart design solutions, interventions to improve the level of urban technology and finally also the promotion of campaigns to increase the level of citizen involvement with public authority initiatives.

The fourth and last pillar, which is also implicitly necessary for the application of the other three is called Collaborative Thinking and promotes the deployment of a common effort oriented toward cooperation and partnership with the key actors and stakeholder involved in the process. In order to reach superior sustainable outcomes, it is required an articulated and cross-field view that departs from the traditional compartmentalised vision. The CRC for Water Sensitive Cities explicitly calls for this collaboration, that often takes the form of long-term collaboration between key urban stakeholders. Within this group, we usually include the local governments and, more generally, public authorities with decision-making power, regulatory agencies, researchers from the academic world and all the citizens that are affected by those initiatives. The fundamental actions that are required by the fourth approach are identifying and leverage a common vision, understanding each one's standpoint (the reasons underlying it and the goals that is trying to reach trough it) and deploy a univocal mental scheme that will form the shared meeting ground on which evaluate whether or not to take a specific course of actions.

In addition to this theoretical framework, the main actors of a decision-making process need solid tools that can provide them support and guidance which, in turn, allows them to exploit these four perspective for reaching tangible results. One of the tools that is proposed in the paper is called Transition Dynamics Framework. There are in fact many phases that we have to pass through before the transition process is over and we can assess the results. According to the theoretical framework, we can split the sustainable transition process in six phases. The first phase emerges with the identification of the problem that we want to tackle (issue emergence phase, followed by the issue definition phase, in which we define what caused the problem that we want to solve. This requires the development of a shared understanding about the issue, what originated it and what consequences will it bring, which represents the third phase. The next two phases, called knowledge dissemination and policy practice diffusion, efforts are made in order to bring the stakeholders on the same page and to develop shared solutions. Thanks to this two 'preparatory phases', if properly conducted, the sixth one (embedding new practice), which involves spreading the practice among a broader audience, should be greatly simplified. In this context, the Transition Framework provides both a theoretical framework and a practice tool to understand each phase and the best actions that can be executed. Specifically, it helps creating a deep insight of the socio-technical environment in which stakeholder operate and locating those drivers that can generate significant, practical changes. The tool allows to define six categories of enabling factors, that play a relevant role in each one of the six transition phases mentioned above. This factors are:

- Champions
- Platforms for connecting
- Knowledge
- Projects and applications
- Technical guidance
- Administrative guidance

In this context, the job of the TDF is to understand, for each transition phase, if one or many of these variables is missing. With this new understanding of the context, the actors involved in the decision-making process can give relevance and prominence to many alternative ideas and projects, that can ultimately better tackle the issue to be addressed. Thus the importance and the relevance of this tool lies in the fact that it offers a cooperative process, in which the most relevant actors can meet and reach an agreement for what the best solution is. Moreover, it allows to understand if the actions that are about to be taken need a refocusing and whether all the enabling factors that can support them are present. An example of a municipality that adopted this practice can be found in the city of Perth. Thanks to the use of the TDF tool, it emerged a community of organized and committed stakeholders that now lead the transition of the city toward a water-sensitive layout. Over a period of five years, the city has developed a water-sensitive vision, in addition to the widespread trend of water-sensitive oriented actions. In this context, a fundamental role has been played by the model's own enabling conditions. In the graph below, one can see a set of such drivers, which have been differentiated according to the current transitional phase.[14]

Transition phase	Champions	Platforms for connecting	Knowledge	Projects and applications	Implementation guidance	
					Technical	Administrative
1. Issue emergence	Issue activists		Issue highlighted	Issue examined		
2. Issue definition	Individual champions	Sharing concerns & ideas	Causes & impacts examined	Solutions explored	Data & evidence collected	
3. Shared understanding & issue agreement	Connected champions	Developing a collective voice	Solutions developed	Solutions experimented with	Preliminary practical guidance	Administrative instruments explored
4. Knowledge dissemination	Influential champions	Building broad support	Solutions advanced	Solutions demonstrated at scale	Refined guidance & design tools	Early policy & performance standards
5. Policy and practice diffusion	Government agency champions	Expanding the community of practice	Capacity building	Widespread implementation & learning	Guidance for implementation & cross-sector	Refined policy & standards, early regulation
6. Embedding new practice	Multi-stakeholder networks	Guiding consistent application	Monitoring & evaluation	Standardisation & refinement	Comprehensive standardised guidance	Comprehensive policy & regulation

Figure 4. Transition Dynamics Framework, Setting Out Key Enabling Factors over the Course of a Transition (from Issue Emergence through to the Embedding of a New Practice)

2.5 Barriers to WSC implementation.

As much as the intentions and aims of water-sensitive practices are absolutely benign and totally to be encouraged, it must be noted, however, that the transition is happening very slowly, despite the very high urgency of initiatives to protect the world's water resources. The slow pace that is characterizing the transition toward Water Smart Cities reflects the presence of multiple obstacles on the path, making it difficult and impassable. As an end result, the presence of these obstacles dramatically slows down the transformation process; in some cases it even halts it or makes it impossible, as long as these conditions persist. If we want to develop the most effective strategy for our context, we must be able to identify the eventual presence and the magnitude of such obstacles, so that they can be taken into account in the strategy formulation and implementation phases. This topic is addressed in a paper written by Lee, Yigitcanlar and Dawes.[17] It begins by stating that a vast majority of water management strategies are fragmented and they do not consider the complexity and all the urban aspects that are influenced by water management practices. For this reason, in order to design a set of policies that may bring concrete and consistent results, it is necessary to identify the related underlying problematics.

One of the main obstacle is represented by the technological and knowledge requirements that are necessary to effectively deploy a WSC project. A transition that can be sustainable in the long term requires a deep understanding and study of many urban and social factors that it is possible to find within the academic world. Finding a way to create a platform where this intellectual capital can converge and can be exploited to give the transition process a solid theoretical foundation is one of the main actual challenges. Also, it is necessary a continuous dialogue and exchange of experience with the private businesses, as they can provide significant tangible and intangible resources. In fact, the authors state that often " while these technical principles and skills are available the information and skill-sets are often only available to certain departments or are scattered amongst different professions that are involved in urban water management, but do not necessarily work together". Another aspect related to this issue is the high levels of investments that are required to obtain, on the one hand, sufficient technological capital to support the innovation process and, on the other hand, the complex and articulated network of infrastructures, which are the cornerstone of the entire WSC and which make it possible to translate advances in the technological world into concrete benefits for the community. As an example, despite the public perception of being more expensive, WSUD have pretty much similar costs as of those of traditional solutions. However, due to the high time and resources employed in the designing and approval stages, the costs of WSUD infrastructures is usually higher than the average traditional infrastructure. However, as stated by the authors, "potential advantages, such as better environmental outcomes and preservation of quality of life for communities are often the benefits in the longer term". In this scenario, the public-decision maker has the difficult task of being able to generate and attract new intellectual capital, providing occasions to spread this enhanced knowledge (such as fairs, conventions and debates) and simultaneously stimulate and attract financial resources that can sustain the transition process. A very complex and holistic set of policies has to be deployed in order for all these element to act together as an integrated system. Therefore, a pool of politicians, strategists and engineers with high skill is identifiable as one of the building blocks for enabling such a transition.

Another critical aspect related with what we have just discussed is represented by the change agents, which can also be referred to as “champions. Such individuals stand out because they possess a skill set that allows them to translate the basic theoretical principles of water-sensitive practices into concrete actions. Although laws often already incorporate these principles, there is often a lack of people with the multidimensional perspective needed to translate them into actual practices. Change agents, possessing such characteristics, are defined by the authors as true 'brokers' of scientific knowledge who are able to communicate this knowledge in such a way that the main actors involved understand and internalise it. The role of the champions is therefore fundamental because they can not only promote and stimulate innovation, but they can also mix it within the community’s culture, thus fostering a vibrant and committed approach to sustainable innovations. Thus, the main challenge is represented here by being able to stimulate the enhancement of the human capital, so that an increasing number of champions may be available. Also, once this phase is over, being able to identify such champions and to co-ordinate their efforts toward a sustainable transition is another complicated aspect.

Another difficulty is represented by the fragmented level of knowledge that we have about water sensitive practices. Despite the theme has been deeply studied and discussed, it is still difficult to find a common consensus about it. Often, many debates and dissonances arise when it comes to defining which practices are sustainable and why; which goals to pursue and which instruments to use to measure these results. In this sense, a common effort in creating an understanding of common guidelines proves necessary. A lack of widespread and shared practices may represent an obstacle to the transition, as it may cause misalignment between the main actors involved in the process. The authors individuate point at the “lack of consistent standards and knowledge amongst stakeholders” as “the biggest impedements to implementing WSUD strategies”. It is therefore encouraged the promotion of common guidelines that can provide shared principles and practices, that are coherent and viable also during the planning and implementation phase.

The aspects that may represent a barrier to adoption and implementation of WSC projects are discussed also in another article, written by van Hattum et al.[18] In this case, a business perspective is taken, according to which these barriers are divided into those that are relevant for the demand side and those for the supply side. Among the former, it is possible to identify:

1. Time pressures: this problem is articulated in two forms. The former concerns the lack of alignment between the time horizon of investments (usually short term) and the one in which it will be possible to measure results (i.e. the medium/long term). This may discourage the most risk averse investors, especially when there is no clear connection between the effort incurred and the benefits created, especially when these benefits are linked to rare events, such as catastrophic climatic events. The latter instead refers to the mismatch between long-term effect of climate change and the short-term orientation of policy makers. Often, following adverse events, public decision makers create a sense of urgency that often results in immediate action to repair the damage and restore the previous situation. In doing so, however, long-term goals are often overlooked in favour of short-term wins that may be more valuable in the eyes of urban stakeholders. As a partial consequence of the hydro-social contract, many citizens lack adequate knowledge of the long-term effects that are induced by climate change and therefore do not put pressure on the public authority to ensure that actions taken today also take into account possible future scenarios.
2. Regulations: the vast majority of the policies promoted today support Business-as-usual approaches, usually posing an obstacle to more sustainable practices. It is thus necessary to promote a flexible regulation systems, that allows the adoption of sustainable water management practices. Also, thanks to the significant and profound transformation that is required, it is also possible to find new and uncontested spaces in the legal system that can be shaped according to water management principles.
3. Uncertainties about effective climate adaptation strategies: the doubt as to when and with what intensity future environmental scenarios will manifest themselves profoundly influences the ability to adopt future policies, which may turn out to be wholly unsuitable for the new conditions to come. This means that, without a solid

theoretical base and solid practical evidences, it is almost impossible to implement policies that can be environmentally sustainable in the long-term.

4. Lack of a clear problem owner: when considering a WSC project, it is important to remember that the actors involved in the whole process are both public and private; each one of them has to perform a specific task that is required for the whole system to be operative. Thus, a frequent issue is that it is difficult to locate who is in charge of the project and should thus possess higher decisional power. Such sustainable projects often involve the public authorities (usually public spaces are put at the service of these development ideas) that require efforts and resources coming form the private business sphere. A critical point for the success of such projects is therefore being able to identify, at the project definition stage, who will be responsible for it and how much decision-making power will be entrusted to all the actors along the chain. Also, this 'individuation' obstacle manifest itself also when considering the benefits produced by the transition project. Such positive effects are often distributed in the entire community, thus making it harder to identify who gets these benefits and how much of it. This difficulty gains even more importance if we consider that, through a smart taxation system, it is possible to provide adequate funds to finance the project. However, raising such funds becomes incredibly more difficult if it becomes difficult to link the benefit received by an individual with a financial levy, often in the form of a contribution. When considering WSC projects, it is thus fundamental to consider the peculiar features of it, such as direct and indirect costs that can manifest in a wide and strongly differentiated geographic area.
5. Integrated solutions in a sectorial world: Very often in these projects, the desired results are achieved through the use of integrated solutions, i.e. they need the coordinated operation of several aspects in order to deliver superior benefits to the community. Thus, all the practices that use the traditional sectorial vision are remarkably unsuitable for such transition projects, that instead require a multi-disciplinary and cross sector view. A compartmental view can be considered as an obstacle to the diffusion of sustainable practices, particularly if we consider that this is the most common approach utilised in the financial world.

On the other side of the analysis, it is possible to find the supply-side obstacles, that may hinder the adoption of WSC projects and redirect their resources toward other typologies of investment. Among them, it is possible to recognize:

1. Unconvincing business proposition: in the eye of the financial resource provider, it is very important to be able to use a solid business case as proof that investments will generate future revenue and repay the initial effort. It is therefore crucial to leverage all the most urgent aspects that would be met through such projects, such as ensuring the safety of citizens and the well-being of the economic system.
2. Lack of documentation: this aspect is strictly interrelated with the previous one. In fact, those that have the decisional power to allocate financial resources need a strong documentation, which contains all the information and the data that are required to evaluate whether to invest in the project or not. The information contained in such documentation should at least cover the costs and the benefits associated with the idea, along with some type of empirical evidence that can provide support to the financial decision maker. Considering that WSC projects often involve innovative goals, that are both difficult to define and to measure, being able to provide enough evidence supporting the business idea may represent one of the most important obstacles to the adoption of such projects.
3. Too small company for very large projects: considering the scale at which these changes have to take place, often the enterprises that offer themselves to provide resources are way to small for the effort that has to be done. For example, the funds required for enabling the Cloudburst Management plan in Copenhagen required almost 500 millions of euros. Thus, the largest company should be more prone to encourage these innovation projects, as they possess more resources, more human capital and also experience that can help in allowing such changes.

CHAPTER 3

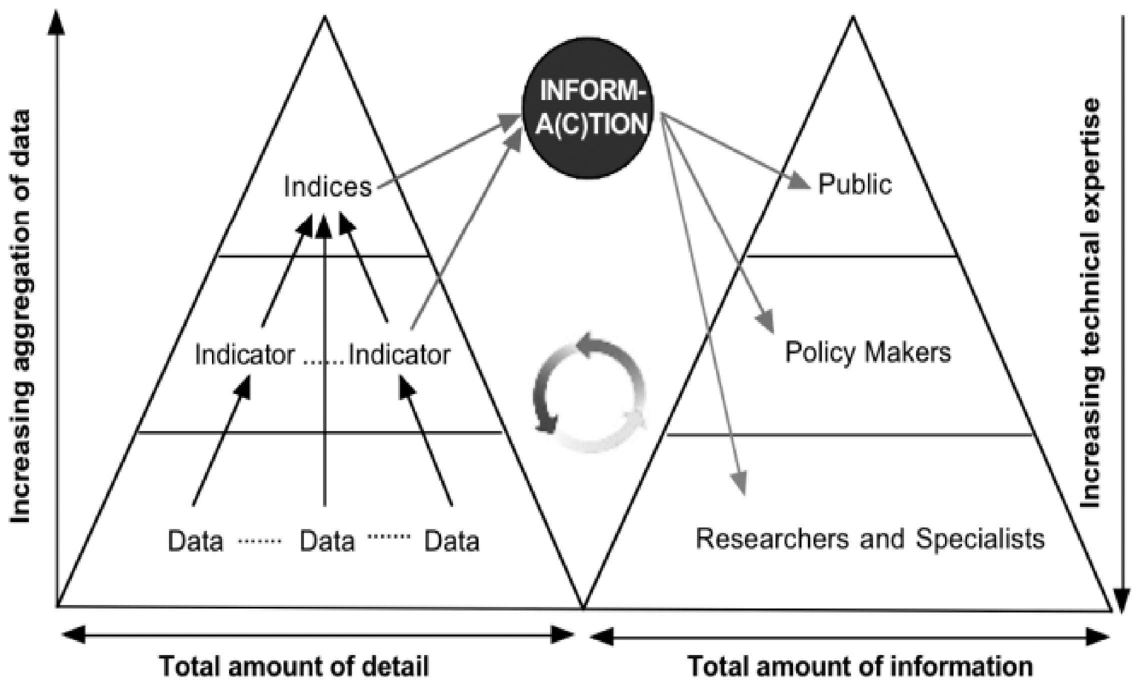
In this chapter we will present the main tools through which it is possible to effectively manage and run an urban water sustainable project. Despite the variety and deepness of the benefits that are made available through these initiatives, still there is little to no consensus on how to measure these results. This difficulty is further increased if we consider that often we have to measure intangible effects, that are difficult to grasp through numbers. As an example, how it is possible to clearly show and communicate whether a city has improved on the dimensions of liveability and sustainability? What urban variables can show a performance improvement on these dimensions, and how can we measure that? The uncertainty and lack of a univocal and unambiguous system of measures of urban water management performance is one of the most important obstacles that has to be addressed in order for the practice to be widespread. Clear and tangible indicators are fundamental in the project approval phase, provided that they establish on what dimensions should we improve and how the adoption of water sensitive practices can help in enhancing results. Moreover, robust and coherent indicators will be required also by the financial investors, who will call for concrete measures that are fundamental to reach the final goal, which is a Water Smart City. Also, the providers of financial resources will need concrete measures that can serve as proof of the goodness and feasibility of the project, as well as being able to estimate the costs and profits associated with such a process. Having a set of clearly defined goals is also useful when creating a narration about Water Smart Cities, that can involve and engage all the actors that play a major role in enabling the change to happen. Finally, performance indexes will also be necessary for the public decision maker. They will in fact be fundamental at each stage of the transition to assess whether the results achieved are satisfactory and it is therefore possible to move on to the next stage or whether rethinking and redesigning is necessary before proceeding.

Therefore, in this chapter we will present a brief definition of the concept of sustainability index, what are its main features and purpose. Then, we will present an historical analysis of the pas water sustainability indexes, in order to show what good has been done in the past and which aspects still need improvement. Finally, we will present an innovative tool called the Water Sensitive Index which is a ground-breaking method used to benchmark and assess the actual levels of water sensitivity of a certain urban area. This measuring tool, developed by the Cooperative Research Centre for Water Sensitive Cities (to which we shall henceforth refer using the acronym CRCWSC) mixes qualitative and quantitative methods that are necessary to evaluate the performance of a specific municipality. The importance, usefulness and application possibilities of this index will also be supported through the presentation of suitable business cases.

3.1 Sustainability indexes: an overview

Sustainability indices are still a relatively innovative concept today, considering the fact that they were conceived in 1992. Indeed, in that year, at the United Nations Summit in Rio De Janeiro, the need to develop principles and guidelines to guide sustainable development began to be discussed for the first time. The concrete result of this effort is the drafting of Agenda 21, which provides the more than 170 participating countries with a list of sustainability indicators. The objective then became to improve the value of these indices so as to be able to measure the effectiveness of the development policies implemented. The Rio Summit triggered a significant initial ripple effect: a vast array of international and non-profit organisations, local and state governments and even large groups of private companies channelled their resources and efforts into achieving a global performance that met the sustainability parameters enshrined in the Agenda. Today, a wide range of indicators and indices are used in multiple social settings and at different hierarchical levels (regional, state, international).

Jianguo Wu tries to narrow the scope by focusing on the definition of sustainability indicators. Broadly speaking, an indicator can be defined as "a variable or an aggregate of multiple related variables whose values can provide information about the conditions or trajectories of a system or phenomenon of interest".[19] In order for it to be considered useful, it is necessary a reference benchmark, through which it is possible to assess the actual state and the desired goal. As an example, by measuring the levels of CO2 in the air it is possible to understand the level of air pollution, that can encourage the adoption of corrective actions. It is also necessary for these indicators to be based on a set of data that can be quantified and/or measured by a yardstick that allows one to assess any improvement or deterioration compared to the initial situation. An example in this sense is all qualitative values, such as the level of happiness of a population or the level of quality of life. The author then states that “Sustainability indicators are indicators that provide information on the state, dynamics, and underlying drivers of human–environmental systems”. Usually, it is possible to spot such indicators whenever time limits or objective targets are included into the measurement and evaluation of them. Moreover, within the term “sustainability” we are used to include not only environmental, but also economic and social variables that have specific features and operations. It is quite clear that the scenario before us is characterised by being very diverse and composed of a wide range of performance measurement tools. However, this complexity is fundamental in describing the interrelatedness of multiple phenomena that take place in different time and space, but that interact with each other. As the current situation shows, the coexistence of too many indicators can increase the complexity of operations, reducing common understanding of the issues and often resulting in ineffective, if not contradictory and counterproductive actions. For this reason, indicators are often mixed together through the use of mathematical formulas to eventually create indices. They can thus be defined as 'the combination of two or more indicators with each other'. In addition, a multitude of actors are involved in the creation of such tools: the information that will form their fundamental theoretical basis is generated and collected by researchers and members of the academic world, and then placed at the service of the public decision-maker who has the task of implementing the policies necessary to achieve the set objectives. Citizens can also benefit from such tools: thanks to them, the current and



ideal state of the art can be communicated in a simple and intuitive way, so that an exciting and engaging narrative of the sustainable transition process can be created. These aspects therefore make it clear to us why Sustainability Indexes are one of the most widely used performance assessment tools globally. Below is a diagram depicting the index generation process, together with all the actors involved in the different stages of the process.

3.2 Previous applications of Sustainability Indexes to water management practices

Also, with regard to the sustainability of urban water resources, many indicators have been developed over time, in order to grasp and analyze the complex and articulated performance of an urban layout. We will present a couple of the most famous tools that are today employed. As we will see, these indicators distinguish themselves because they do a great job in trying to grasp the complex reality of a municipality. However, we will also see some of their limitations and in which areas do they manifest. Through this analysis, it will then be possible to present a new and substantially different, sustainability index.

The first example of the list is represented by the Arcadis Sustainable Cities Index, which focuses its attention on issues related to urban prosperity. The main idea underlying the construction of this index is that cities must be evaluated not only on the level of their economic progress, but also on the actual levels of environmental urban health, along with the perceived level of quality of life of the citizens. The starting point is represented by an urban landscape that focuses its efforts toward environment preservation while providing inclusive opportunities for its citizens. Thanks to these elements, it is possible to obtain a long term growth and success, which are summarised with the term “prosperity”. It is interesting to notice that, in this scenario, the COVID-19 pandemic is referred to as an event with some positive aspects; it is seen as the opportunity to set a “Great Reset” in which all the pressing issues of sustainability can be implemented in practice through the adoption of an holistic and integrated view. In the words of the Arcadis CEO, “Cities must take a holistic approach, developing a sustainability plan that invests equally in the three pillars of Planet, People and Profit”.[20] This assessment tool works by ranking more than 100 cities around the world along three basic dimensions, which are: Planet, People, Profit. It is interesting to notice that, despite each of the three dimensions have the same weight in the Index, they are still sequentially evaluated following the order presented above. This means that a small preference is given to cities that focus more on human-environmental aspects. As an example, a redesign and rethinking process is required for a municipality that has good levels of productivity but low level on the other dimensions. However, this does not justify the complete exclusion of the economic logic when approaching sustainability issues: cities that perform well on human and environmental dimensions. are destined to fail if they are not supported by a sound economic system that guarantees to generate those profits that will then be reinvested for sustainability-oriented initiatives. This dynamic is most often found in fast-growing markets and developing nations where, despite good economic performance, little or nothing is done for the People and Planet dimensions. So the main challenge that municipalities have to face today is represented by the need to find a dynamic equilibrium between each of these three pillars. We will now focus our attention towards the three building blocks of the index, that are:

- **Planet:** which captures the environmental-related aspects of a municipality. This dimension is then broken down into several sub-topics that are: citizens' needs (expressed through air pollution and the availability of public green spaces), an assessment of the long-term impact of adopted policies and a quantification of the level of investment in low-carbon impact infrastructures (represented by the use of renewable energy and/or the deployment of a sustainable transport network
- **People:** which assesses the social performance of a municipality, that is evaluated in terms of the quality of urban life. This is, in turn composed of many elements. The first is the individual well-being, which is measured, on the social side, through health or education levels and, on the economic side, through the levels of work-life balance and income inequality. An additional dimension that quantifies the urban liveability, which is expressed in term of the WI-FI availability in public spaces and the degree of broadband accessibility.
- **Profit:** which tries to evaluate the level of attractiveness of the business environment, along with the overall public and private economic performance. This is done by examining the actual business infrastructure and the business performance. The main areas of interest here are represented by the levels of economic development and employment, but also by the degree of access to productive

factors. It is interesting to notice that one of the dimensions through which the robustness of an economic system is rated is also the commercial transport infrastructure, which simplifies the exchange of products and services not only between private companies, but also between companies and purchasing citizens

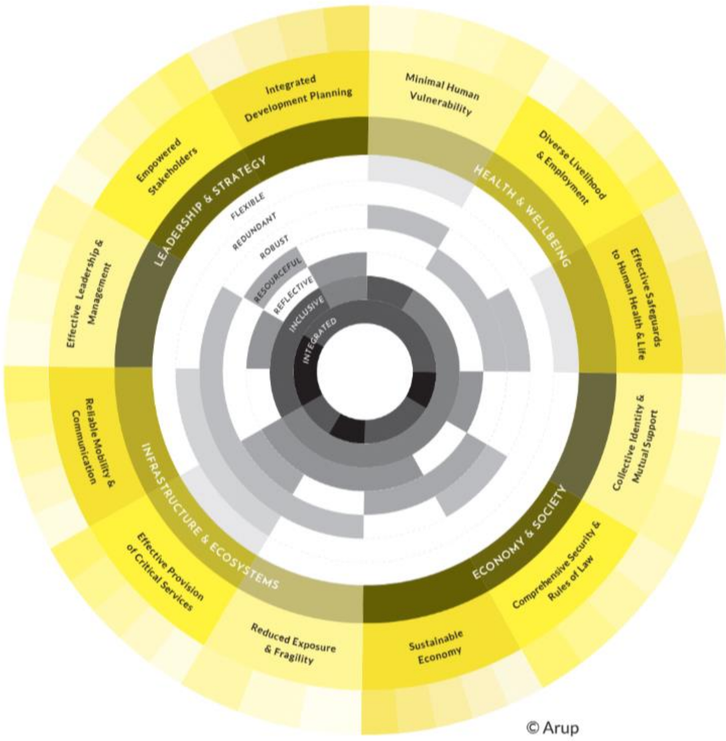
It is interesting to notice that, despite the good metrics offered, this sustainability index is criticized in the paper "Water Sensitive Cities Index: a diagnostic tool to assess water sensitivity and guide management actions".[21]Specifically it is written that good efforts are present here in trying to evaluate the urban performance on dimensions such as resource consumption, public health and the relationship between economic aspects and water management practices. However, it is also stated that "urban social and governance aspects of integrated water management" are not taken into account by the model proposed by Arcadis. On the other hand, these aspects are crucial in order to understand, on the one hand, what actions can be taken to safeguard the city's existing water supply, and, on the other hand, what would be the expected reaction of citizens to such actions and what initiatives can be promoted to align the citizens' vision with that of the public-decision maker.

Another tool that will be analyzed is the City Resilience Index, which is presented in a paper published by The Rockefeller Foundation. It is defined as "a set of tools and approaches for cities to explore and evaluate their resilience, enhancing their ability to build sound strategies and plans for a strong future"[23]. It is interesting to notice that, compared with the previous one, this tool aims at measuring and assessing the performance of an urban setup over time. Therefore, the city is only competing against itself, in an effort to continuously improve the current conditions. A first difference is therefore that competitive benchmarking, in which municipalities are compared to each other to decide who is the best, is removed. Considering all the many differences from city to city, comparing two realities that may have profoundly different structures may not produce useful results. Instead, it is much more useful to understand the difference from one's own past state and what improvements can be implemented to improve this index. Nonetheless, a common framework of reference, provided by the CRI, can encourage reciprocal dialogue and the exchange of information about the best-in-class practices. Another interesting aspect of the framework presented is a new focus oriented toward resilience. The concept is defined as “the capacity of cities to function, so that the people living and working in cities survive and thrive no matter what stresses or shocks they encounter.” Thus, a resilient city moves away from the traditional approach of risk management, which is usually based on the practice of management by exceptions, and instead exploits a systemic and dynamic approach, in which the presence of adverse events is taken into account. In this way, it will be possible to have a city that succeeds in executing its basic economic and social functions, even in high-risk contexts, rather than focusing on practices of risk prevention or damage restoration.

The index is composed of four key dimensions, which are the essential components of the resilience of a city:

- **Health and well-being:** this concept is tightly related with the people living and working within the urban boundaries, particularly regarding its capacity in providing basic-needs’ services during difficult times. This includes an evaluation of the ability in delivering livelihood opportunities and healthcare infrastructures.
- **Economy and society:** the focus here is centered on the socio-economic infrastructure, particularly how it allows to the citizens to leave peacefully and act as a community. A great importance here is given also to the surrounding environment that can promote well being and a sense of community and its measured through all the public and private initiatives that can promote and foster it.
- **Infrastructure and environment:** this aspect is instead related to the geographical location of the city. It is considered robust if it has an infrastructure and an ecosystem that can provide basic services even under high pressure or stress conditions. Examples in this sense are water supply, the ability to distribute energy and resilient transportation systems.
- **Leadership and strategy:** the underlying guiding principle here is the knowledge, expressed in the ability to study past practices in order to evaluate and plan adequate future initiatives. This will require a strong leadership that is, on one side, able of coordinating all the urban actors and, on the other, capable of providing them with all the information that are needed in order to raise awareness about the actual state and what actions can be done.

This set of indexes is, in turn, composed of 12 goals to which the city should get in the medium/long term. However, the model keeps into account the possibility that different goals may have different importance for the public agenda of the various cities. In order to reach these results a group of 52 indicators has been created in order to assess the levels of urban resilience. Furthermore, thanks to evidence coming from both the theoretical and empirical world, these indicators integrate seven different pillars that are indicated by the authors to be the fundamental qualities that characterise a resilient city. In particular, to be so, a municipality is commanded to be: flexible, redundant, robust, resourceful, reflective, inclusive and integrated. The image below encapsulates the intricate framework that has been adopted in multiple cities around the world including Hong Kong, Cape Town, Liverpool, New Orleans and Sao Paulo.



According with the paper of Rogers et al., the model successfully presents a wide range of fundamental aspects to be considered when managing a city, which are deeply interrelated and require a profound understanding and well-considered actions. However, the main criticism is that many aspects of urban water management are ignored. This creates a situation in which, in the face of an effective but highly articulated and complex model, fundamental dimensions such as that of urban water cycle management are referred to as residual, if not completely ignored.

Shifting the focus toward a more general focus, the authors believe that one of the main weaknesses of these methodologies is that, although they introduce concepts that are useful for water management, none of them manage to capture the full range of "social, governance, economic, liveability, multi-functional and adaptive attributes that are defining attributes of water sensitivity".[21]They also proceed to analyze the past literature that raised many doubts about the validity of these indicators, especially if we consider the policies that should embody them. Indeed, during the process of drafting laws, they are very often ignored, with the result that impactful and effective changes are not produced. Furthermore, it also questioned the method through which data are gathered, which could often differ between that of local authorities and their colleagues at state level. This problem makes such data almost unusable and prevents the possibility of promoting internal comparisons between various hierarchies of public decision makers. This aspect has also to be related with the possible presence of spatial and temporal gaps in the database, that may be incomplete or may be adopting different measuring standard and frequencies. If the data are corrupted, incomplete or inconsistent the possibility of comparing and integrating data from subjects with similar characteristics or facing the same problems is prevented. Finally, one of the biggest risks associated with the use of weak indicators is that they could confuse policy makers and end up promoting actions that are not sufficiently effective or, in worse cases, that could be counterproductive and harmful. This will ultimately result in a great deal of resources, time and effort being wasted. In the light of the analysis just conducted, the CRCWSC has developed the Water Sensitive Index which has several features:

- It is a reliable and scientific-based instrument
- It has a holistic approach toward water sensitivity
- It is applicable at different scales and organizational levels, with distinctive characteristics for each of them
- It can be employed for cross-comparisons
- It has well-defined benefits and keeps in consideration the practical necessities of decision and policy makers.

3.3 The Water Sensitive Index (WSI) framework

The index was created through a lengthy research and design process that lasted two years, between 2014 and 2016. Members of the CRCWSC, a group of researchers and a committee representing the industry' sector were involved in the development process, so as to connect those from academic world (who are usually in charge of creating the information that makes up the indices) with private business (which is usually the 'ultimate consumer' of such information). By tapping into the existing literature, it was possible for the people involved to locate more than 200 indicators, coming from a multitude of different frameworks, each one with it distinctive features. This allowed the researchers to develop a primitive and rudimentary index, that was tested for the first time in the City of Knox and City of Port Phillip, in order to obtain an initial set of raw data on the field. After the test was over, phase two started. It consisted of a first round of corrections that led to a redefinition of the index's structure, based on what was learnt in the previous tests. It is also notable that, at this stage, a significant effort was conducted also toward the clarification of the indicator descriptions, in order to foster cross-comparisons between different cities. The redefined index was then tested in three different locations: one was a metropolitan area, while the others concerned more restricted geographical areas. After a further adjustment of the indicator components, we moved into the validation phase, in which the instrument is used to assess the performance of more than 10 Australian cities. Once again, experience led to adjustments on the index. Moreover, a training programme and guide were designed and created, in preparation for the launch of the tool in 2018. To date, many municipalities have made extensive use of these workshops offered by the CRCWSC, which have enabled a quick and easy adoption of the WSI.

Shifting our focus toward the Water Sensitive Index alone, it is described by the authors as having "the ability to benchmark cities at the metropolitan or municipal scale, based on performance against a range of urban water indicators across the societal, biophysical and ecological dimensions that characterise a WSC."[21]This allows to have a clear ranking of the city took into consideration, along with a clear definition of the strength areas and those that need improvements. The index is composed of 7 goals, which are:

1) *Ensure good water sensitive governance*
2) *Increase community capital*
3) *Achieve equity of essential services*
4) *Improve productivity and resource efficiency*
5) *Improve ecological health*
6) *Ensure quality urban spaces*
7) *Promote adaptive infrastructure*

For this broad set of objectives, a range of 34 indicators was designed to measure performance on each of these dimensions. Each of them will be then given a score ranging from 1 to 5, that will best represent the current scenario for that city; also half scores are allowed when the municipality stands between two absolute values, however, the use of the other decimal points is not permitted, as we do not possess an instrument that provides such a precise measurement and such values would in any case not have a major impact on the particles to be implemented. It is interesting to notice that many indicators are composed of qualitative variables, which allows to the public decision maker to evaluate how they take different values depending on the context. However, the same score presented above will be finally given to them too, so that it is possible to have an objective and quantifiable starting point. Therefore, it seems clear that the index possesses a well-defined structure, along with a scoring guide that allows to apply the method even in the face of changing conditions.

Together with this robust and articulated index, the evaluation model presented can also count on a workshop process that provides additional support to participating organisations. It consists of a group of trained and certified experts, that will provide some guidance on how to conduct the evaluation in their own town. Additionally, the scores of those who relied on this methodology are published on a huge database, that provides opportunities for competitive benchmarking, along with a huge pool of data that can help in stimulating further developments and corrections of the Index. This process requires the presence of a large group of different urban actors: usually they range from 15 to 50, an, among them, it is possible to find local municipalities, consultants, developers, representative members from research institutes. Before the beginning of the workshop, participants are provided with all the definitions and key concept that are fundamental in order to understand the framework and the indicators composing it. Despite an all-around knowledge of the subject is not mandatory, still it helps in simplifying the process, especially the discussion phase. After the preliminary stages have been completed, the middle stage takes place, in which a certain score is attributed to each goal. This also requires a precise evaluation of each underlying indicator. In this context a central role is played by the 'facilitator' which helps the participants in understanding what the indicator is trying to measure, thus simplifying the cognitive and assessment process. Participants of the event are encouraged to evaluate individually each indicator, through the use of a voting system. A discussion between each relevant actor is then fostered, in order for the parts to reach a common agreement about the score to give to specific indicator. This happens thanks also to the use of past and tacit knowledge, along with a deep understanding of the empirical evidences presented. After the scores are settled by common agreement, we move on to the final phase of the workshop, in which all available courses of action are evaluated and which ones present a better fit for their town. Usually here the possible courses of action are divided in three categories: actions with high consensus and supported by strong evidence, actions with medium consensus among actors that don't have enough evidence and actions with low aggregated consensus and a lack of supporting proofs. In the final phases of the event, the data created through it is disseminated among the participants, to stimulate a group reflection on the current situation and an identification of the most critical areas in need of intervention. There is also the possibility to go even deeper, with the possibility to access a detailed report made by CRCWSC’ consultants that offer a profound analysis of the municipality taken into account. Therefore, it is now clear that the both the Water Sensitive Index and the workshop-based methodology have many beneficial aspects. On one side, it offers the opportunity to bring together actors who often operate in the same context and, above all, their ideas and visions, which are often conflicting and prevent effective policies. On the other hand, the presence of qualified and trained personnel may help stimulate a critical reflection of the current situation, together with an analysis of the available empirical data, in order to select only those policies that respect the limits imposed by both processes. Below it is possible to find a detailed description of all the theoretical evaluations that are necessary for effective scoring. The reference in this case is goal number 3. In addition, a sequential diagram of all the steps of the CRCWSC is provided.

Table 3
Example indicator rating descriptions and scoring guidance.

Goal	3	Achieve equity of essential services
Indicator	3.4	Equitable and affordable access to amenity values of water-related assets
Ratings:	1:	Water-related assets do not provide amenity benefits in most areas of the city. Enjoyment of available amenity benefits of assets comes at a relatively high cost for some households.
	2:	Water-related assets provide amenity values in some areas of the city. These areas are not easily accessible and enjoyment of these benefits comes at a relatively high cost for some households.
	3:	Water-related assets provide amenity values in large areas of the city. These areas are mostly accessible and come at a moderate cost for some households.
	4:	Water-related assets provide amenity values in most areas of the city. These areas are highly accessible and enjoyment of these benefits comes at low cost.
	5:	Water-related assets provide amenity values in all areas of the city and are implemented to improve lower socio-economic areas. These areas are highly accessible and enjoyment of these benefits comes at no cost.
Key definitions		• *Water-related assets*: natural assets (e.g. rivers, creeks, bays, beaches) and built assets (e.g. constructed wetlands, retarding basins, reservoirs, biofilters, cycle paths and walking trails beside water assets) • *Accessibility:* people can readily access the amenity in terms of location (distribution and distance to travel), affordability (financial and time cost), universality (all people including those with a disability)
Guiding questions		• What amenity values are associated with water-related assets? Where are they located? Are they easily accessible? • Are the amenity values of most water- related assets accessible to different income groups? Are there admission costs? • How are the relative costs to enjoy such amenities distributed between different income groups?
Examples of relevant features that may be observed		• Waterways and water-related assets that are channelised may have few attractive elements and exclude people • Retarding/detention basins may be single purpose and protected by fencing or alternatively, may be landscaped and incorporate community facilities such as trails and shelters • Water reservoirs may incorporate parklands • Coastline or inlets backing onto private property with no public access means low accessibility
Examples of evidence		• Policy documents and strategic plans • GIS maps of the distribution of water assets with high amenity values

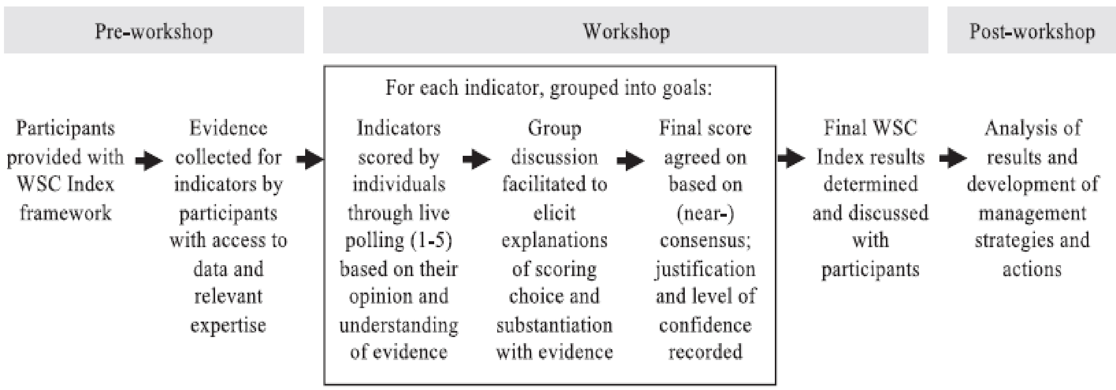


Fig. 3. Participatory process for applying the Water Sensitive Cities Index.

CHAPTER 4

We will present here some of the most recent and interesting use cases that are helpful in developing a path toward Water Smart Cities. Interestingly, a large percentage of the business cases presented took place in Australia, demonstrating that the country is a leading model in the implementation and application of Water Sensitive practices.

The case studies will present the same approach and utilise the same methodology of the Water Sensitive Index, presented in the previous chapter, to demonstrate its robustness and reliability as a fundamental tool to succeed in becoming a Smart Water City. This methodology will also be applied to several Australian realities, which differ in terms of territorial extension, complexity of the problems solved and the number and type of actors involved in the process.

4.1 Sidney

The first example is represented by the metropolitan area of Sidney, which was analyzed for five months, from June to October 2017. During this period, many interviews and workshops took place in order to assess the present situation and develop both a vision and a strategy. In the beginning of the experiment, a collective discussion between the participants was encouraged with a focus on the past: specifically, a conceptual map of the different evolutionary phases of the city is drawn up. In particular, attention is paid to which political, social and economic factors triggered it and which urban drivers simplified it and finally made it possible. In this context, it was also studied whether the urban water systems had actually improved or worsened as a result of these changes. This can be exploited in order to gain knowledge about the internal urban dynamics and their interactions, and how to maneuver and coordinate them in order to easen the future processes of change. As of today, the city established itself as one of the largest and most populous in the world, which is also about to face a new wave of population growth. In this context, a key role was played by water system services, which allowed, on the one hand, the initial survival of the first local populations and, on the other hand, the socio-economic development that led to the city's current state: as Sydney grew, the urban water network became larger and more articulated and evolved accordingly. Therefore, its evolution and modernisation is closely linked to the development of urban spaces. Due to this acknowledgment, public interest has shifted from reducing costs towards achieving higher levels of urban liveability.

In the subsequent phase of the experimentation, the central point was the identification of all the major weaknesses of the current system, along with the most pressing challenges that need to be addressed immediately. In particular, it was asked what could have been the magnitude of the impact of climate change, overpopulation (the municipality is expected to register 8 millions of inhabitants by 2050), excessive urbanization and globalization on the actual practices related to the management of the urban hydric resources. This has led to identify extreme weather conditions as one of the most imminent threats to the city. On one side, high temperatures may have a major impact on actual urban heat levels, which could in turn result into drought periods, increased levels of stress on water sources and the possibility of spreading fires. This is particularly worrying if we consider the closeness of the urban spaces with the Blue Mountains and Royal National natural parks. Their importance is further increased by the fact that these green areas represent the main reservoirs of water resources that are used in the metropolis. On the other hand, if the level of rainfall exceeds the average by too much, the risk of flooding increases, with the possibility of major damage to major waterways, such as sewer overflows. Other critical dimensions have also been identified, related to urban development trends, such as the effects of globalisation, which raise the issue of ensuring equitable access to water and its services for all citizens. Furthermore, the effects of population growth and increasing rates of urbanisation are reflected in increased stress placed on available water resources and the risk of erosion of currently available green spaces. The latter is particularly true for the western part of the metropolis, which is in close contact with the surrounding natural parks. However, these critical issues also present room for growth and learning opportunities. As argued in the paper Benchmarking, Envisioning and Transition Planning for a Water Sensitive Greater Sydney: Final Case Report: “The diversity of cultural backgrounds, differences in quality of environments and access to opportunity in Greater Sydney suggest that a greater focus on the role of water system services in supporting social equity will be important. This could include creating community connections to water and water-related environments, which in turn creates opportunities for learning and social cohesion”. New practices that deviate from the business-as-usual approach will allow for innovative solutions for water delivery services and urban spaces. Regarding the second aspect in particular, respondents predicted that private green spaces will become smaller and smaller (in order to accommodate a greater number of citizens), further emphasising the importance of having large communal green lungs, accessible by an increasing number of citizens.

In a second round of workshops, the focus was turned towards the future, in particular, towards the development of a vision that could inspire key stakeholders to action. Therefore, guidelines representing desired future states were collectively developed. Among the many that emerged, a few are presented:

- The hydric resources and those of other typologies must be managed in an holistic and integrated manner, in order to ensure a certain level of sustainability between demand and offer for them in the medium/long period
- Water technolgies and infrastructures are the necessary substrate that ensure the city's transition to a WSC

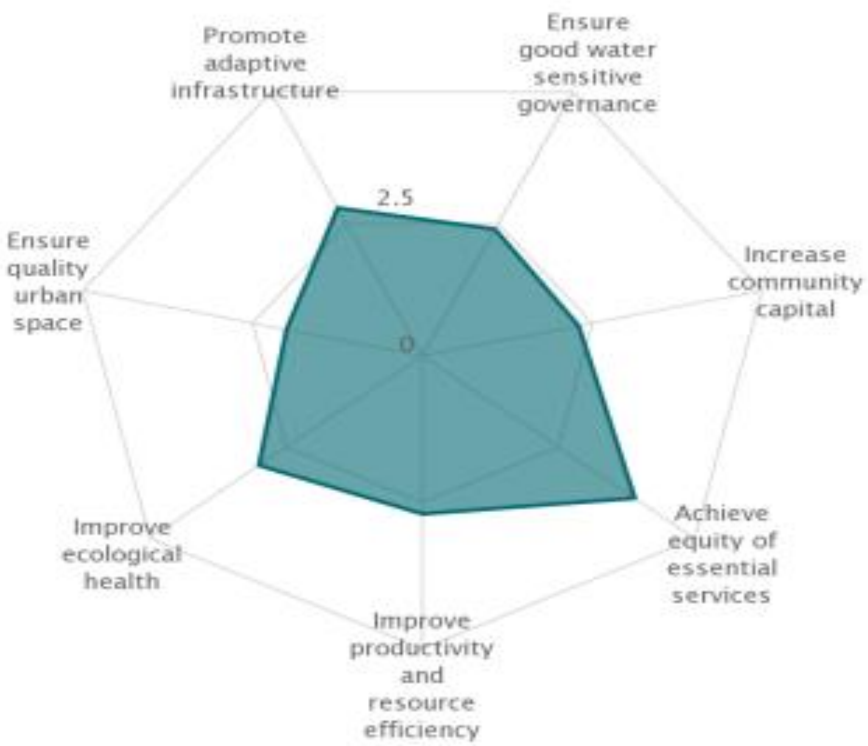


Figure 8: WSC Index goal scores for Greater Sydney (shaded teal area)

- Thanks to the deployment of flexible and integrated water services, it is possible to grant to the citizens a widespread welfare and sense of security
- A water-oriented governance promotes the use of collaborative, dynamic and flexible approaches between the various city stakeholders

Thanks to the collective development of objectives and desired results, it was possible to create a framework in which all stakeholders can act in a choral manner, inspired by their common goals. It also opens up the possibility of reviewing the actions already undertaken so that they can be evaluated and reoriented in light of the new, jointly drafted guidelines.

In a third phase of the study, the current situation in Sydney was benchmarked. The assessment is necessary to enable a transition to a Water Sensitive City, which must be developed in accordance with the principles derived from the previous round of discussions and debates. To do this, the same framework as the Water Sensitive City Index, presented in

Table 1: WSC Index scores (goals and indicators) for Greater Sydney

WSC Index Goal and Indicators	Score /5	WSC Index Goal and Indicators	Score /5
1. Ensure good water sensitive governance	**2.4**	**4. Improve productivity and resource efficiency**	**2.7**
1.1 Knowledge, skills and organisational capacity	2.0	4.1 Benefits across other sectors because of water-related services	2.5
1.2 Water is key element in city planning and design	2.0	4.2 Low GHG emission in water sector	3.0
1.3 Cross-sector institutional arrangements and processes	2.0	4.3 Low end-user potable water demand	3.5
1.4 Public engagement, participation and transparency	2.5	4.4 Water-related commercial and economic opportunities	2.0
1.5 Leadership, long-term vision and commitment	2.5	4.5 Maximised resource recovery	2.5
1.6 Water resourcing and funding to deliver broad societal value	2.5	**5. Improve ecological health**	**3.0**
1.7 Equitable representation of perspectives	2.5	5.1 Healthy and biodiverse habitat	2.0
2. Increase community capital	**2.3**	5.2 Surface water quality and flows	3.0
2.1 Water literacy	3.0	5.3 Groundwater quality and replenishment	3.0
2.2 Connection with water	3.0	5.4 Protect existing areas of high ecological value	4.0
2.3 Shared ownership, management and responsibility for water assets	2.0	**6. Ensure quality urban space**	**2.0**
2.4 Community preparedness and response to extreme events	2.0	6.1 Activating connected urban green and blue space	2.5
2.5 Indigenous involvement in water planning	1.5	6.2 Urban elements functioning as part of the urban water system	2.0
3. Achieve equity of essential services	**3.9**	6.3 Vegetation coverage	1.5
3.1 Equitable access to safe and secure water supply	5.0	**7. Promote adaptive infrastructure**	**2.8**
3.2 Equitable access to safe and reliable sanitation	4.5	7.1 Diverse fit-for-purpose water supply system	3.0
3.3 Equitable access to flood protection	3.0	7.2 Multi-functional water system infrastructure	2.5
3.4 Equitable and affordable access to amenity values of water-related assets	3.0	7.3 Integration and intelligent control	2.5
		7.4 Robust infrastructure	3.0
		7.5 Infrastructure and ownership at multiple scales	2.5
		7.6 Adequate maintenance	3.0

chapter three of the paper, was used. In particular, in a first step, the degree of achievement of the 7 goals required for a Water Sensitive City was analysed, giving each of them a value between 0 and 5, based on the degree of achievement and completion of the goal. The results are summarised in a generic way in the graph that can be found a few rows above, while at the bottom a detailed table lists the results achieved by the city of Sydney for each sub-component of each goal. As can be seen, the metropolis performs above average on the dimensions 'Achieve equity of essential services' and 'Improve ecological health', whose scores were 3.9/5 and 3/5 respectively. In contrast, low scores were recorded in the dimensions 'Ensure quality urban space' (2/5) and 'Increase community capital' (2.3/5).

This was followed by a state-of-the-art analysis of the metropolis, which was evaluated using the methodology presented in Chapter 2. Specifically, considering the transition framework from Water Supply City to Water Sensitive City, a "percentage of completion" is given for each evolutionary sentence through which the city must pass in order to be considered Water Sensitive. This analysis is conducted to understand the city's current situation and to be able to outline strategies and actions to effectively complete the transition. The image below summarises the results that have been obtained for Sydney. In the opinion of the authors, the city is renowned for its water security services, which determines a full score for being a Water Supply City. The main sources of supply are located in the natural areas surrounding the city: in particular, the exploitation of the Warragamba Dam, which meets approximately 4/5 of the metropolis' water needs. This infrastructure guarantees a continuous, stable and lasting supply of water resources and can also count on the presence of a water desalination plant, which is designed to supply 1.5 million citizens, in case poor rains and droughts compromise the dam's capacity. A full score is also obtained in the Sewered City dimension. This is due to the fact that wastewater services are provided for almost 2 million people, thus ensuring a minimum level of cleanliness and hygiene of the water resources available to citizens. In particular, the community can rely on an intricate sewage system and the presence of numerous wastewater treatment plants. One weakness of the system is the risk of overflow, especially during heavy rainfall. Furthermore, ample room for improvement remains in the treatment and recycling of all those water resources that are returned to the natural environment through discharge into the sea. Interestingly, a relatively low score was obtained for the Drained City dimension (67%). Indeed, the municipality has a solid network to ensure drainage services and generally operates efficiently. However, there are several areas that, on the contrary, are excessively exposed to the risk of flooding, such as all populated areas near the George and Cook rivers. Another area exposed to such risk is the eastern part of the city, which, although exposed to intense but short-lived phenomena, nevertheless demonstrates the fact that some areas are not sufficiently equipped to cope with such worst-case scenarios. Any policy aimed at improving this situation will help Sydney to score fully on this dimension. The importance of this aspect is not to be underestimated: as stated in a round of collective discussion: "Flooding is a hot topic in Sydney - we are needing to increase housing yet we are pushing development into floodplains." The fourth dimension of analysis again gives a high score to the metropolis, which is considered a 94 per cent complete Waterway City. This result is the result of an effort to change water management practices and policies, as well as an effort by the citizens' initiative, who have launched more initiatives to clean up the beaches in the Sydney Harbour area. In addition, a series of restrictive policies (such as the direct removal of certain industries and the prohibition of the use of highly polluting chemicals) has led to a decline in the level of manufacturing activities in recent years, with a reduction in water contamination. However, there is still room for improvement, which is why the city did not receive full marks. According to the report's authors, the level of knowledge and awareness of water protection issues is still quite low among citizens, who often lack the systemic vision needed to assess the impact of their choices on the urban water cycle.

It is interesting now to turn our attention to the last two dimensions of analysis which, in our framework presented in Chapter 2, were only imagined and hypothesised by the authors as future states and ideals to be achieved. Sydney is considered to be a 31% Water Cycle City due to a progressive diversification of water sources from which to draw. There are many examples of this: the widespread use of containers to collect rainwater, the sharing of water resources from private wells and springs, and stormwater harvesting and reuse. However, with regard to the latter practice, important and significant progress can be made. Indeed, the main obstacle is the current institutional structure that manages water resources and consists of, on the one hand, local municipal councils and, on the other hand, Sidney Water, a government-owned organisation that deals with the protection and distribution of water. Since both of these bodies have the power to decide on stormwater management practices, there is a need to develop cooperative practices, which to date, however, are scarce, if not completely absent. Another problematic aspect is the vision with which these bodies operate: often considerations regarding the health of waterway and stormwater infrastructure are made without taking into account water supply and wastewater aspects. Despite these difficulties, many local councils are taking the initiative to use increasingly water-sensitive practices, although the authors point out how the adoption of WSUD facilities occurs in a non-linear fashion, with rates of adoption of new facilities (or innovation of existing ones) fluctuating. On the other hand, significant efforts have been made to install all water-saving infrastructures that have been widely deployed throughout the territory. This was in response to the problems generated by the Millennium Drought of the early 2000s. Thanks to this event, which had a great impact on the Australian population, the authors claim that today 'Greater Sydney is seen as a world leader in reducing residential potable water usage'. The first facility designed to recycle water was built in Rouse Hill and saves 2.5 gigalitres of water for a community of more than 30,000 people. In this sense, practices geared towards recycling water resources used within the households have resulted in a water saving and recycling of 36 gigalitres of water (a gigalitre is a unit of measurement that corresponds to 109 litres; thus, in the urban area of Greater Sidney, approximately 360,000,000 litres have been saved in a single year. If we also take into account all recycling practices that are not the direct responsibility of Sidney Waters, then the potentially achievable savings rise to 70 GL, thus doubling the magnitude of the beneficial effects generated by such practices for citizens. As for the ideal state to be achieved, the Water Sensitive City, the metropolis is currently only 8% complete. In fact, a positive value has been placed on this dimension in that, the main water and sanitation services are accessible to all citizens. These services are also distinguished by their safety (i.e. they are guaranteed even in extreme weather conditions) and their low price. The attention paid by local governments to the preservation of green areas with high ecological and environmental potential is another aspect that contributes to the city's score on this dimension. However, it is clear that a significant effort still needs to be made to improve along this dimension. In particular, the city must be able to guarantee a high level of ecosystem protection and restoration, while at the same time guaranteeing all other basic water services. The chart below provides a summary of what has just been discussed for each dimension of analysis considered.

The analysis just conducted demonstrates that Sidney is one of the most advanced cities in terms of water resources management and protection practices. In fact, the city can count on an integrated system of infrastructures and policies that allow the achievement of a series of characteristics that must be possessed by the water services provided to the citizens, such as a stable supply of water resources or the presence of drainage channels for waste water. In line with the authors' opinion, the metropolis' current scenario places it at the forefront of the transition towards a Water Smart City and thus represents one of the few examples in the world of a community that has begun a transition towards a more ecological and balanced future. It should be noted, however, that despite this leadership, the results achieved in the 'Water Cycle' and 'Water Sensitive' dimensions are still rather low. This is an indication of the fact that although the city is on the right path of growth and development, there is still a great deal of room for improvement in current practices, which need greater coordination and integration of policies, together with the development of a widely shared vision consistent with the objectives, all supported, in turn, by a proactive and deeply involved and engaged community of stakeholders in the transition.[24]

4.2 Bendigo

The second case presented, in which the same methodology used for Sydney is applied, concerns the city of Bendigo. The city is located about 150 kilometres from Melbourne and has an urban population of about 76,000. Again, the starting point of the analysis is an initial workshop, in which participants had to analyse and understand past patterns in water management. The end result consists of a timeline in which each identified historical phase corresponds to a particular orientation towards water management. This is done so that on the one hand, past best practices and even the worst (or at least the least effective) can be identified. Furthermore, on the other hand, participants are made clear about the starting condition of the city and which current characteristics are the result of the legacy of past water management practices. Through this analysis, it is possible to construct a diagram depicting the water story of Bendigo, which is summarised in the diagram below. Interestingly, more than 200 years ago, the local indigenous peoples had already developed a holistic view of the surrounding waterways, which were not only seen as a reservoir from which to draw water resources, but also as relevant to the well-being of the surrounding natural environment. This view was completely overturned following the discovery of gold deposits in the vicinity of the city, a historic event that began a period of intensive mining. The result was a high degree of deforestation and land dredging, with a strong impact on the health of the underlying aquifers on the one hand, and on the quality of the available water, which was often polluted by the waste from the various production and mining activities, on the other. In short, the city's gold rush led to a scenario of intense droughts and water shortages, alternating with times when excessive rainfall resulted in massive flooding. In more recent years, the city has instead undertaken a decisive change of direction from the trend that saw it as an increasingly polluted industrial city with diminishing public green spaces. In particular, in the late 1980s and early 1990s, a series of refurbishments were passed to improve the services dedicated to water supply to citizens. In addition, the city began to develop a planning vision that takes into account the surrounding water reservoirs, along with a substantial package of investments in water infrastructure and the modernisation of existing infrastructure. In the most recent years of the new millennium, all practices related to landcare, i.e. actions aimed at protecting the wellbeing of Bendigo's land, have taken on increasing importance, with important repercussions on the quantity and quality of water resources that can be found. Again, the Millennium Drought had a significant impact on the lives and behaviour of citizens. In response to this drought, citizens adopted water-saving techniques, among which it is interesting to note the use of succulent plants, which are resistant to high temperatures and need little water. On the other hand, the local government has implemented stringent regulations to promote the saving of water resources. All this has been done with a view to achieving a high level of resilience for the city, which, due to the destruction of its natural heritage, has been subject to extreme weather events. The concrete result of these efforts can be seen, on the one hand, in the inclusion of minimum WSUD standards in the Victoria Planning Provision and, on the other hand, in the implementation of the 'Water for Victoria' plan, which made available USD 30.8 million to promote sustainable groundwater management practices.

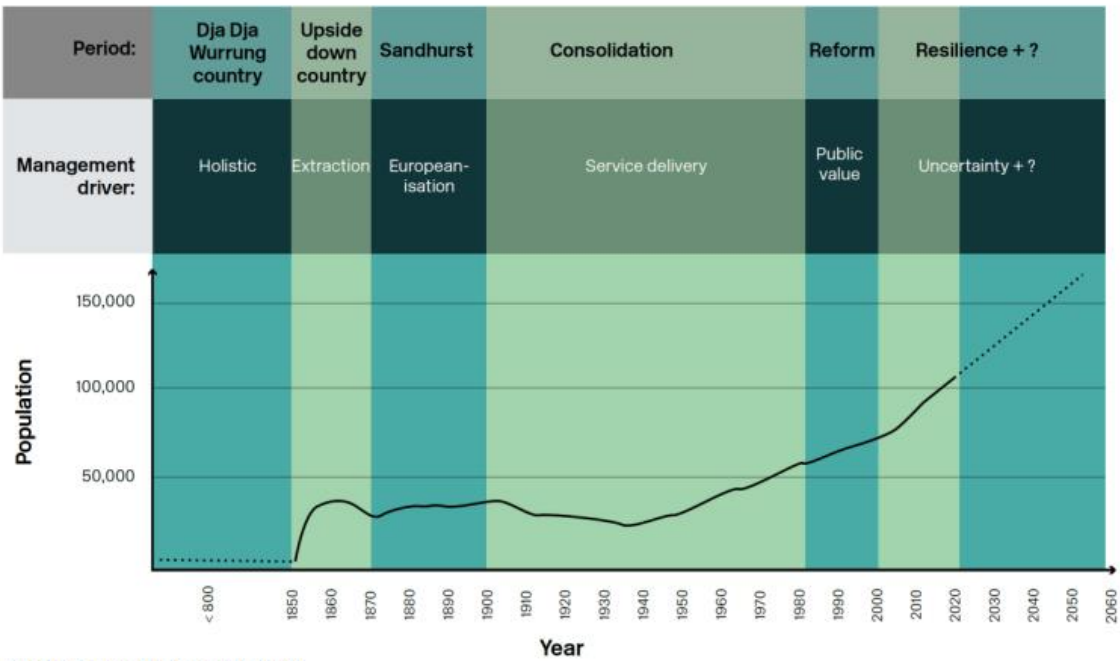


Figure 2. Bendigo's water story

In a second analysis phase, all stakeholders involved in the transformation process were asked about the desired future state of their city. In particular, each participant was asked what the ideal Bendigo would look like in the year 2068. At this juncture, there was also an opportunity to reflect on what temperatures will be recorded or are expected to be recorded in thirty years' time. According to the scenario outlined it is likely that the average temperature in Bendigo will be 2° higher than it is today, with important consequences for the city's water management practices, which may be affected by periods of particularly high temperatures. Although there is a great deal of uncertainty regarding the models presented at this stage of discussion, however, one important point that emerged is that the city will face a reduction in available surface water. at the same time, an increase in temperatures will lead to an increase in demand for water resources, placing these basins under greater stress. In 1/3 workshops the knowledge obtained through the first two phases of analysis

Table 1. WSC Index scores (Goals and Indicators) for Bendigo

WSC Index Goal and Indicators	Score /5	WSC Index Goal and Indicators	Score /5
1. Ensure good water sensitive governance	**2.8**	**4. Improve productivity and resource efficiency**	**2.4**
1.1 Knowledge, skills and organisational capacity	3.0	4.1 Benefits across other sectors because of water-related services	3.0
1.2 Water is key element in city planning and design	2.5	4.2 Low GHG emission in water sector	1.0
1.3 Cross-sector institutional arrangements and processes	2.5	4.3 Low end-user potable water demand	3.0
1.4 Public engagement, participation and transparency	3.0	4.4 Water-related commercial and economic opportunities	3.0
1.5 Leadership, long-term vision and commitment	3.0	4.5 Maximised resource recovery	2.0
1.6 Water resourcing and funding to deliver broad societal value	3.0	**5. Improve ecological health**	**2.0**
1.7 Equitable representation of perspectives	2.5	5.1 Healthy and biodiverse habitat	2.0
2. Increase community capital	**2.8**	5.2 Surface water quality and flows	2.0
2.1 Water literacy	3.0	5.3 Groundwater quality and replenishment	2.0
2.2 Connection with water	3.0	5.4 Protect existing areas of high ecological value	2.0
2.3 Shared ownership, management and responsibility for water assets	2.5	**6. Ensure quality urban space**	**2.2**
2.4 Community preparedness and response to extreme events	2.5	6.1 Activating connected urban green and blue space	3.0
2.5 Indigenous involvement in water planning	3.0	6.2 Urban elements functioning as part of the urban water system	1.5
3. Achieve equity of essential services	**4.0**	6.3 Vegetation coverage	2.0
3.1 Equitable access to safe and secure water supply	5.0	**7. Promote adaptive infrastructure**	**2.8**
3.2 Equitable access to safe and reliable sanitation	4.5	7.1 Diverse fit-for-purpose water supply system	2.5
3.3 Equitable access to flood protection	4.0	7.2 Multi-functional water system infrastructure	3.0
3.4 Equitable and affordable access to amenity values of water-related assets	2.5	7.3 Integration and intelligent control	2.0
		7.4 Robust infrastructure	3.0
		7.5 Infrastructure and ownership at multiple scales	3.0
		7.6 Adequate maintenance	3.0

concerning Bendigo's past and future are blended to create a common vision that can guide future sustainability practices. This vision is articulated in the form of desired outcomes that the community and the city government aim to achieve. In particular, 3 goals emerged:

1) Bendigo's citizens are happy and healthy, and they live within the boundaries of a sustainable city
2) All watercourses in Bendigo are in good health and are integrated into the natural environment through which they pass
3) Bendigo is resistant and resilient to extreme weather events. When they occur, the city can rely on intertwined and adaptive methodologies for urban water management

In the fourth phase of the experiment, an analysis of the city's present situation was carried out using the WSC Index framework presented in the previous chapters. This methodology is divided into two phases: in the first, the city's current performance against 7 sustainability goals is assessed using this index. For each of them, the city obtains a scoring from zero to 5. In the second phase, known as the benchmarking phase, the current state of the city is assessed against the 6 possible city states it can achieve. The results obtained through the use of the WSC Index are summarised in the graph to the side, and in more detail in the table below. As can be seen, the city of Bendigo managed to obtain very high values for goal number 3 "achieve equity of essential services", for which it obtained a score of 4/5. Slightly above average and therefore positive values were recorded for goals number 1, "ensure good water sensitive governance", 2 "increase community capital" and 7 "promote adaptive infrastructure". Finally, goal number 4 recorded a value of 2.4, slightly below the average. On the other hand, relatively low values were recorded for goals number 5 and number 6 whose values, two and 2.2, are quite different from the average values recorded in the other dimensions. In the last phase of the analysis, known as the benchmarking phase, a percentage of completion is assigned for each of the six states the city must achieve. this analysis is summarised in a circular graph which can be found at the bottom of this page. For the water supply analysis dimension, the city achieved the highest score, 100%. This is due to the fact that the city is connected to the Goulburn river system, which is an intricate network of rivers and bodies of water connecting several cities in South Australia, including Bendigo. In this way, the local government can centrally manage the resources and make them available to citizens at a low cost and with a high level of hygiene in the water supplied. This has enabled it to meet the standards set by the safe drinking water regulation. However, it should be noted that the city obtains its water resources from other regions, thus creating the risk of placing these regions under severe water stress during periods of high temperatures or extreme droughts. Similarly, the city scored full marks for the sewered city dimension, for which according to the authors the completion rate is 100 per cent. This emerged from Coliban Water, a public agency that provides waste water services to more than 40,000 urban households and more than 3,000 private properties located in rural or out-of-town areas. Bendigo is also considered a 100% complete drained site. This was achieved through the development of better modelling practices that allowed public decision makers to better understand when a flood would occur and with what intensity. thanks to such a system the city is able to be operational and is able to cope with adverse weather events. In addition, the city's planning scheme was also recently updated to take into account the possible floods that the new forecasting model is able to predict.

The city also possesses high levels of amenity and liveability values, that are of great value to the citizens who use and benefit from them. in addition, the authors record a high level of accessibility to water sensitive infrastructure and to all sustainable assets. The ultimate goal driving the design and implementation of water sensitive facilities is to be able to deliver widespread well-being and value within the community. Also in this case as in the one analysed above the adoption of WSUD facilities is not very constant. In fact, although such infrastructures can be found within the city, their adoption and use is very low in rural areas. In spite of all these positive aspects, however, it must be noted that the city has a relatively low number of waterways and that the quality of the existing ones is rather low, especially with regard to the hygiene of the water supplied through them. For these reasons, Bendigo is considered an 82% complete waterway city.

Regarding the fifth dimension of analysis, Bendigo is considered a Water Cycle city completed at 31%. Upstream of the cycle, the city can in fact rely on a wide range of water supply methods. In particular, potable water is extracted by the Coliban system while non-potable water is mainly collected within urban spaces through the use of rainwater tanks and bores. Moreover, as we have seen above, the millennium drought phenomenon has led to an increased use of water-saving practices. In addition to this, numerous educational programmes have been promoted to increase citizens' awareness of the issue and thus incentivise them to reduce water consumption. However, once the emergency ended, increases in water use were recorded, with higher risk of stress on water reservoirs. Finally, a fundamental principle of this type of city is the integrated management of the water system in which citizens, government and representatives of the private business sector participate. This idea has already been formally integrated into the policies promoted by the local government, however, according to the authors, a greater level of commitment is needed for the promotion and dissemination of such practices. finally, the city of bendigo scored 8% on the water sensitive City dimension. this is mainly due to the fact that water supply and services that ensure the health of citizens are available to the public, are safe and are offered at a fair price for all segments of the population. With this in mind, the local government is planning to build two stormwater harvesting infrastructures that would be used to irrigate public land and city parks. Although many examples of water infrastructure can be found within the city, there is however a lack of public awareness regarding the positive effects that such infrastructures can bring not only to them, but also to a much

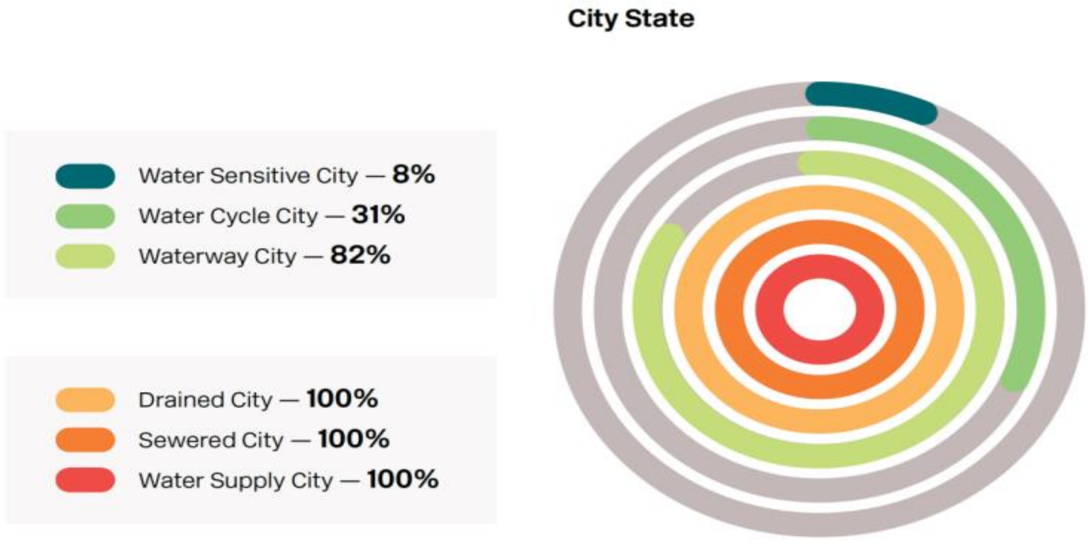


Figure 13. Summary of Bendigo's performance against each city state.

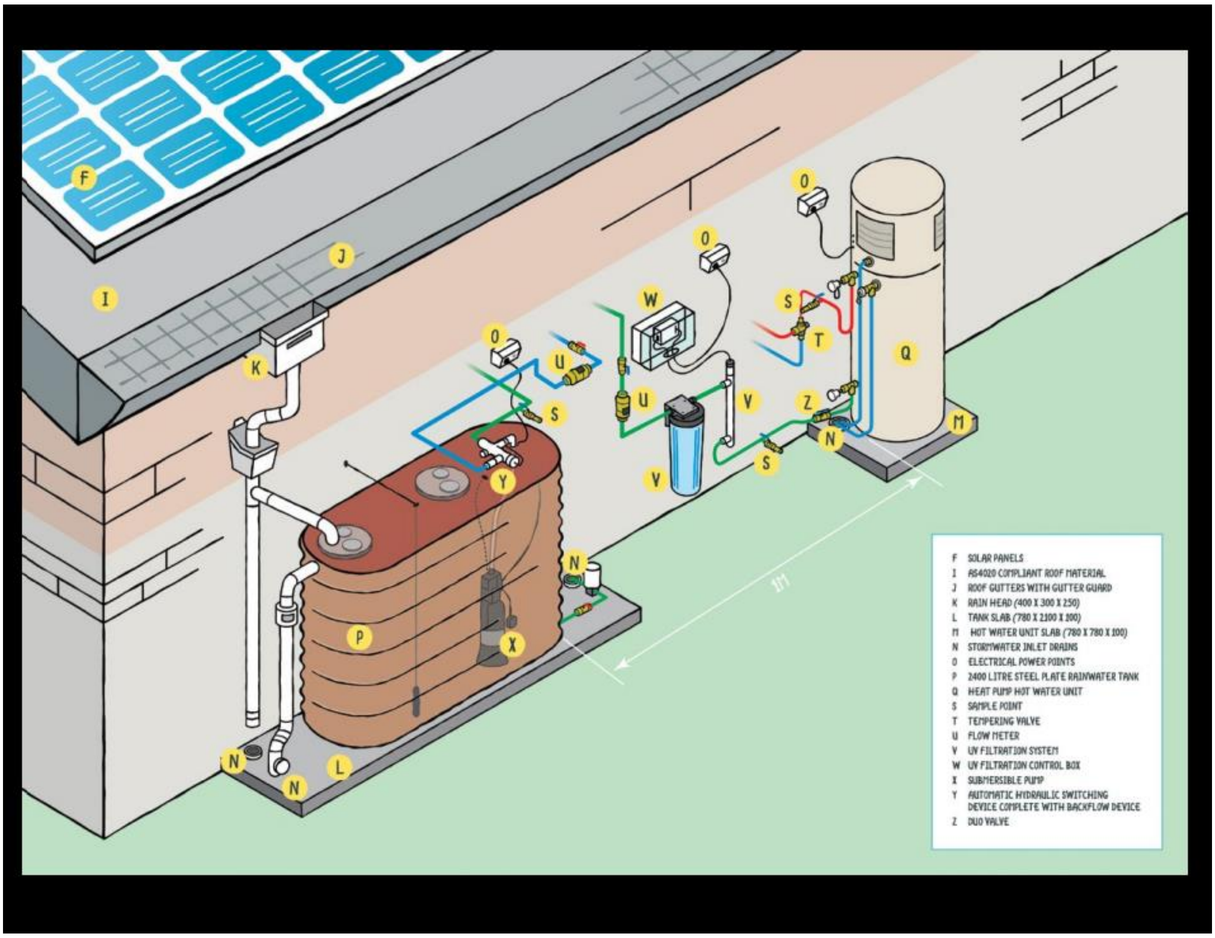
wider audience. According to what is sustained by the authors in the final stages of the analysis, in order to become eligible as a Water Sensitice city 100% complete, Bendigo: “will need to fulfil the multiple objectives of ecosystem protection and restoration, security of supply, flood control, public health, amenity, liveability and economic sustainability, among others”[25]

4.3 Further applications: AQUAREVO

Another very interesting example of smart water management practices is the Aquarevo project studied in a 2017 CRC paper for Water Sensitive Cities. The project, which takes place in the city of Lyndhurst (in the Australian state of Victoria), represents one of the first and largest applications of Rain water harvesting for hot water in the entire region of Victoria. Specifically, the project took place on Evans road, in an area of approximately 40 hectares that includes 460 residential dwellings. The area under study represents a small plot of land within an urban area. In particular, it is located within the suburbs of Lydhurst, and is surrounded by projects that reflect the WSUD approach, as demonstrated by the Lynbrook Estate (located to the northeast of this area) and the Marriott Waters to the south. The project is the result of a collaboration between two actors: on the one hand, the owner of the land, namely South East Water, and on the other, the private company in charge of planning and implementing the sustainable development of this area, Villawood Properties. Let us now analyse the innovations at the basis of the project.

A widespread practice in Australia is to collect rainwater through large containers that are placed above the roof. Resources collected through this method were usually used for water uses defined as 'non-potable'. Examples of such practices are irrigation, water used for toilets and water used for washing clothes. However, water heating systems do not get their resources from rooftops because the water has poor hygiene standards and may pose a threat to health, especially when the water is collected in cities while in rural areas it is also used for drinking. If we consider new settlements where recycled water networks are available and used for 'non-drinking' purposes, cisterns to collect rainwater are used differently. In particular, where rein water thanks can be used for hot water supply, then it is possible to combine these tanks with recycled water. This provides benefits both in terms of stormwater and waste water reduction as well as allowing households to increase the percentage of water supplied through the use of alternative sources. analysing the revo water project more specifically, an innovative rainwater harvesting system was implemented with the aim of reducing the health risks commonly associated with the use of rainwater for hot water reasons. the aim of the project is to demonstrate that this source of water resources can make a significant contribution to counteracting and reducing hot water non-potable demand. More specifically, water from rainfall is filtered and treated with UV rays through a screening process. After being purified, it is redirected to neighbourhood households through a separate supply system, to be used for 'hot water' practices such as showering, bathing and washing clothes. In addition, water that is considered potable by the system is redirected for such uses if precipitation is low. All taps that are contracted to supply Rain water have a label certifying the minimum standards that must be met by the urban developers at Aquarevo. All the equipment and tools required to implement this project are installed and maintained by South East water who will remain the owner of these tools for the next 10 years and will be in charge of supervising and keeping the equipment in good condition. In addition, a monitoring tool called OneBox will be implemented in each household, as it allows the company to remotely control and monitor the supply of water resources to the hot water systems. Furthermore, the temperature of the supplied water can be kept constant through this tool. Aquarevo is therefore a solution with significant impacts. The first and most obvious is the fact that it makes possible the supply of rainwater mixed with recycled water; in the paper that addresses this CASE STUDY, a reduction of up to 70% of potable water resources is expected. furthermore, it is also possible to control and monitor the level of water quality, which is measured in terms of hygiene. In this way it is possible to provide clean water and reduce the health risks associated with poorly hygienic water resources. let us now shift the focus to the technology used in this case to enable this practice of recycling and reusing water resources. The rainwater catchment system is represented graphically at the bottom of this paragraph and has certain characteristics that are:

- A container with a minimum capacity of 2400 litres designed to capture water from roofs with a minimum surface area of at least 100 square metres
- A system for protecting and stabilising gutters in the event of excessive or heavy rainfall and a leaf diverter to remove physical debris that may become trapped during storms
- A water filtering and purification system is a tool for ultraviolet treatment
- A water heater connected to the rainwater harvesting system to heat the water to the desired temperature

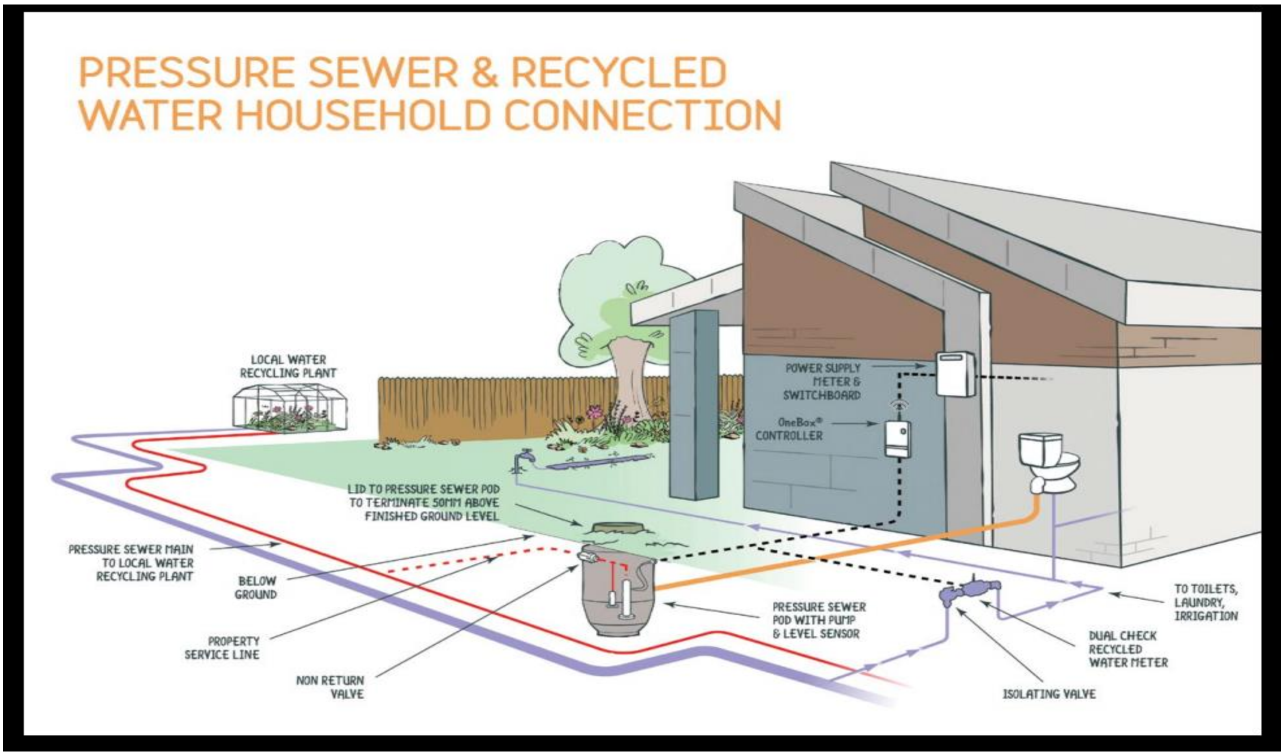


- A piping system connecting the water harvested from the rainfall to the various hot water systems, each of which will have its own particular conduit

The results obtained through the use of this method are manifold. First of all, the use of water from different sources is made possible. Rainwater is captured and reused on site, thus providing an alternative source of water resources that can be used within the household for daily activities. As a result, a significant portion of the demand for water resources that usually takes place within a private household is reduced by up to 35%. The second benefit obtainable through the use of this innovation is the reduction in the clogging of the stormwater system. Normally, rainwater flows into the stormwater system, with the risk that, during periods of high and intense rainfall, the entire system may collapse due to the excessive pressure to which it is subjected. Furthermore, further risks are connected to the displacement of these water resources, which may present a poor level of hygiene or contain pollutants that if released into the environment would cause significant damage. Thanks to this innovation, water resources are not released into the storm drainage system, thus preventing the risk of overuse of the infrastructure that could damage urban waterways. Aquarevo is a project that is also compatible with the supply of recycled water. since recycled water is usually not used for hot water tasks, combining the supply of recycled water with water from ambient rainfall provides additional resources to cope with urban water demand point in particular the authors consider that, through the use of the Aquarevo system, it is possible to achieve savings of up to 70% of the drinking water used inside homes.

A second innovation brought by Aquarevo concerns the management of wastewater. Specifically, these accumulated waters are transferred to a facility already on site within the property. This amplifies and expands the concept of the site as a water treatment location. Through this process it will be possible to provide high quality recycled water to households that can use it for 'non-portables' purposes. In this way it is possible to "reduce the need for drinking water supply to be utilised for non-potable uses". The water supplied is also of high quality and is certified as 'class A', in accordance with the standards and guidelines provided by the Australian Department of Health and Human Services. The innovation in this case is that recycled water is no longer supplied only to those homes that are located in the vicinity of such water treatment areas. On the contrary, the system allows for the treatment and reuse of these resources directly on site, thus enabling anyone interested in such practices to reap the benefits. Aquarevo therefore represents one of the first uses and implementations of decentralised wtaer management technology, thus guaranteeing a 'closed loop' for participating households and reducing the level of stress on the country's main waterways. The presence of an on-site water recycling plant also avoids the transport of wastewater over very long distances to the nearest treatment plant. In addition, thanks to the recycling of water resources, the level of treated waste water released into the environment is significantly reduced. Finally, monetary savings can also be achieved if the system is used in conjunction with an intelligent pressure sewer. In fact, it will reduce stress on the system during periods of heavy rainfall or particularly dry periods, while at the same time allowing it to monitor and manage the flow of the related sewer network in real time.

Within each garden there will be a pressure sewer storage pod with a capacity of 1000 litres. It will hold waste water at the site until South East Water decides to redirect it to the nearest water treatment plant. For such a project to have an effective impact, about 180 houses connected to the system are needed, according to the authors. A summary diagram of this innovation can be found at the end of this paragraph.



The Aquarevo business case also allows us to reflect on the technologies used in the process. thanks to the use of technologies that are based on real-time data collection and the adoption of flexible strategies based on this obtained data pool, it is possible to intelligently manage the entire urban water cycle, also improving the efficiency of the urban water network and reducing the risks related to adverse weather events. In particular, the main solutions adopted concern three types. the first concerns a pressure sewer system capable of transporting waste water to the nearest treatment plants, and then returning purified water that can be used for non-potable purposes to households. Through such solutions, it is possible to close the loop of water, thus enabling the creation of a private loop for each landowner, within which water from rainfall is constantly recycled to carry out household tasks that require it, thus reducing water waste and simultaneously reducing the demand for hydird resources. Another technological solution adopted by South East water is a rainwater harvesting tank that implements a technology called Tank Talk. it receives real time data and weather forecasts for the area and, based on this data, adjusts the water levels within it. Through this tool, it is therefore possible to minimise the level of stress placed on the water infrastructure during periods of particularly heavy rainfall, thus containing the risk of damaging the infrastructure and thus causing possible flooding. The third solution is the onebox device, a smart control tool. The device, which can be found depicted here on the side, is placed on the outside of the house near the rain water tank. Its task will be to collect

real time data such as: the level of rainwater already in the tank, monitoring of all flows passing through the house, information on the pressure level in the pipes, and finally information regarding the use of other energy sources such as solar, electricity and gas. through the use of this tool, a number of benefits can be achieved. First of all, when used in conjunction with Tank Talk it is able to predict rainfall and reduce the amount of water in the tank. in this way more space can be created to collect additional water resources while at the same time reducing the pressure placed on local waterways and stormwater catchment systems. Furthermore, thanks to the possibility of controlling the level of water flows in the pipes, the system allows for the implementation of a smaller sewage system, thus creating capital and operational savings possibilities. Finally, the large amount of data that onebox can collect and process is doubly useful. On the one hand, private landlords will be provided with data regarding their energy consumption, thus being able to stimulate behaviour aimed at reducing this consumption and associated costs. On the other, the system optimises the manteinance process as it is able to quickly identify problems and failures throughout the water network. In this way, it simplifies the problem detection process and through the use of on-time data, pre-emptive manteinance models can be implemented. At the end of this paragraph, a diagram representing the integration of all the solutions just presented can be found.26 The results so far have been encouraging. According to a 2021 report by South East water, homes that have implemented all or some of the solutions proposed by Aquarevo use 45 to 70 per cent less drinking water by replacing it with rainwater or recycled water, which can be put to non-potable use. In addition, it has been shown that through the use of such methodologies and technological solutions, the flow of rainwater passing through the pipes is reduced by up to 20%. This translates into less exposure to the risk of flooding or damage to the waterway network. In addition, research with the University of Melbourne has shown that optimised irrigation practices lead to lower and cooler urban temperatures. South East Water has also partnered with Monash University. Through this partnership, it was possible to demonstrate that it is possible to use cost-efficient sensors to report any spills and illegal dumps that may be found along the entire waterway network, especially in areas most exposed to such situations. [27]

4.4 Further applications: South Bank Rain bank

Another interesting case study is presented by Rain Bank Parkland. The project was developed in the South Bank district, a cultural and recreational area of the city of Brisbane in Australia. The project consisted of 17.5 hectares of public green spaces within the South Bank district. such green spaces are open all year round and are visited by approximately 11 million visitors annually. Within this park, one can find different natural landscapes, water play areas, hiking trails and large green spaces for families and children. according to the report on this initiative, the South Bank area has an annual need for approximately 120 million litres of drinking water (which is needed to supply drinking water to the citizens) and 60 million litres of treated water (which is used to irrigate the area and for sanitation), which is obtained either through rainwater harvesting or through the purification of the water resources already present in the system. within this scenario, the rein Bank is a rainwater harvesting system located in the South Bank parkland district. It collects and treats rainwater resources that are released in a 30-hectare area in the West End district, as can be seen in the picture opposite. The water harvesting area is characterised by being highly urbanised: within it one can find commercial activities and private households. the motivations behind the implementation of this project are manifold. Firstly, the public decision maker in Brisbane recognised the importance of such a park, especially after a period of drought that highlighted the need to provide alternative sources from which to obtain water resources. Furthermore, since the area is very large and the vegetation needs a lot of care and maintenance, a further motivation was found in the need to provide low-cost sources of irrigation. It also had to have the characteristic of sustainability in the medium to long term, i.e. that the irrigation project could be sustainable from a social economic and environmental point of view. to do this, the methodology called 'option analysis' was used, whereby each proposal that was made to cope with the drought affecting the area was carefully evaluated and weighted.

The first step that was taken to implement these innovations was an assessment of the condition of the existing stormwater network, to understand if there was a possibility of retrofitting the existing waterway infrastructure. Through a thorough research and digging process, it was realised that a deeper level of knowledge about the infrastructure needed to be developed. The analysis revealed two main pipes positioned parallel to each other that flow into the Brisbane River: one of the two is referred to as the main Storm water drain, into which all the resources generated by atmospheric precipitation would mainly flow. The second, on the other hand, is an emergency infrastructure that would only come into operation when there is an overflow in the main pipe, to reduce the stress placed on the infrastructure during particularly wet periods. The new rainwater harvesting system also needs a connection to the parklands in order to allow the collected water to reach the parklands. This required the construction of a new pipeline. Another critical aspect of the project concerned the amount of water that would be delivered into the local irrigation system: it was considered necessary to ensure that the amount of water fed into the system was the same as that used in the past so that the irrigation pipes would not be overstressed.

The first innovation presented with this project is called the SHIP, or Stormwater Harvesting Interception Pit. This device was built above the two pipes just mentioned. Inside it is a weir that allows the water to be blocked when the river level is too high, in order to prevent excessive flows inside the pipes during flooding, puts the entire system under high stress. Furthermore, is designed to retain rainwater that arrives from the catchment and can be redirected to the main cisterns. Consequently, a critical aspect of the project was to design a weir that could meet these requirements. the solution came in the form of a mechanically activated weir that can be raised to protect the comma pipe particularly in the event of overloading or overflow. Should the instrument fail to open or lift , it now allows water to pass through and flow, thus avoiding the risk of upstream flooding. Inside the SHIP there is also an instrument that measures water quality, along with a GPT (which means Gross Pollutant Traps) whose function is to separate pollutants from the collected water. There is also a pump which is used to transfer water to the storage tank. This transfer only takes place when certain quantitative and, above all, qualitative water levels are reached; as long as these minimum quality standards are not reached, the system retains the water resources within it and then releases them as soon as these requirements are met.

From an operational point of view, significant considerations were made with regard to the project, as it involved building the ship on an already existing and operational structure. In order to overcome this difficulty, the facility was built "in layers" so as to leave the pipes untouched for as long as possible, thus avoiding the inconvenience caused by the lack of service. Following the construction and implementation of this technology, it turned out that the tidal level was higher than expected. this resulted in salt water entering the system and required the construction of a hinged ti from the gate to the final end of the pipe. at the side of this paragraph you can locate a graph representing this technological solution. the benefits obtained through such a structure are manifold. First of all, the installation of the tool on an existing infrastructure has resulted in a significant reduction in costs, which would have been significantly higher if the entire pipe network had to be built from scratch. Considering that the capex required for the skip was $1.5M, can be said to be a low-cost solution. A further benefit brought by the ship is that it allows the identification of any spills that may occur in the catchment site and prevents them from spilling into the Brisbane River, located not far away. another benefit is related to the fact that the amount of river water entering the network is significantly reduced. By installing a barrier to prevent salt water from entering the system, the quality of the collected water resources is preserved and guaranteed. It also minimises the damage caused by flooding by reducing the water entering the pipes, which are thus subjected to less stress in emergency situations.

A second aspect of this experiment on which much attention was focused concerned the rainwater collection site. In the opinion of the experts, a combination of water balance and stormwater modelling was necessary to The amount of water stress the pipes would be subjected to, especially in times of crisis. This analysis was also conducted to understand the possible correlation between the pipes and flooding in an area close to them. Through the use of these forecast models, an annual demand of 90ML was predicted, which would be earmarked for non-potable usage, such as irrigation and domestic use. The model also predicted that approximately 77ML per year could be captured through this technological solution, together with 32ML of pool backwash water. The forecast model therefore shows how it is possible through such tools to be able to store significant stocks of water that can meet the current demand for non-potable water resources. Through the use of a water balance analysis, it was decided to build a 2 ML cistern, which can meet approximately eighty-five percent of the local demand for non-potable water. The structure, which is entirely positioned below the asphalt level, is divided into two sections: one in charge of storing the collected water resources (whose capacity is 1.75ML) and a second one designed for the collection of purified water. this infrastructure allows for balancing and balancing incoming and outgoing water flows destined for agricultural use. Within this context, a major innovation is represented by the water balance and stormwater network modelling, called XP-SWMM a forecasting tool through which multiple hydrological aspects of the city are considered. In particular, the tool includes analysing, evaluating and managing the following aspects:

- The performance profile of urban pipelines combined with an understanding of the consequences of flooding on the waterways network
- The necessary level of water balance, understood as a level of balance between supply and demand of water resources that is sustainable in the medium7long term
- The ability to predict the city's future water needs under different weather scenarios, which translates into pressure optimisation to make the urban water supply process more efficient

A number of benefits can be achieved through the use of this computer tool. Firstly, through an understanding of the city's hydrological profile, it has been possible to identify excess infrastructure within Brisbane's network. this has led to the elimination OA a reuse of this infrastructure, which has lightened and streamlined the pipe network, leading to a reduction in the level of fixed costs incurred by the public purse. Furthermore, through the use of forecasting methods, it is possible to predict the future scenarios of the city especially during extreme weather conditions, such as droughts or floods point in this way, it is possible to foresee in advance how to use the weir in such a way as to prevent upstream flooding, with consequent dangers and for the city related to the risk of flooding of the river. An application of such a forecasting model can be found at the end of this paragraph. In more detail, a flow risk simulation model is presented that was applied to study the state of Terengganu, Malaysia.

XP-SWMM Hydrodynamic Model for Flood Risk Simulation during Rainy Season along Terengganu River

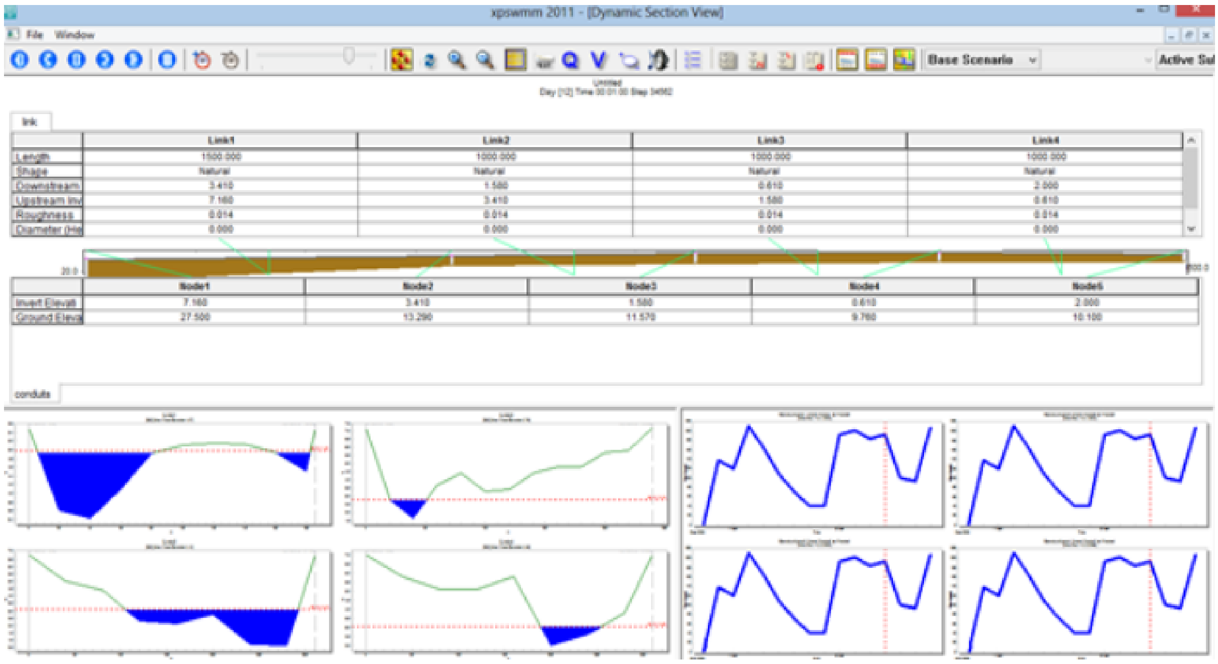


Figure5. The multi-panel view of the simulation results

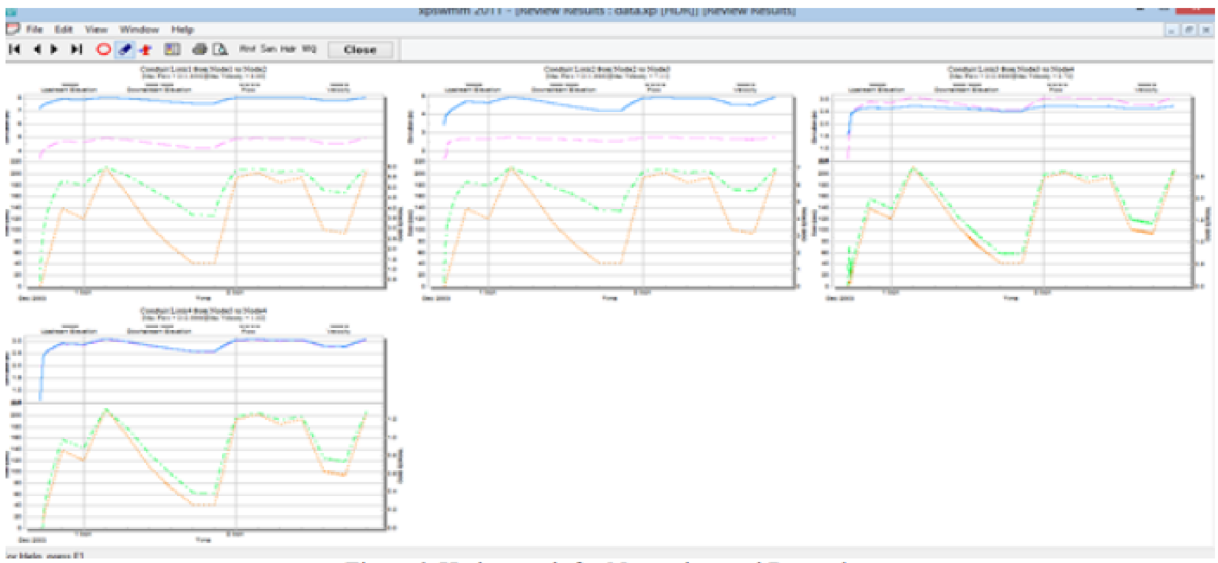
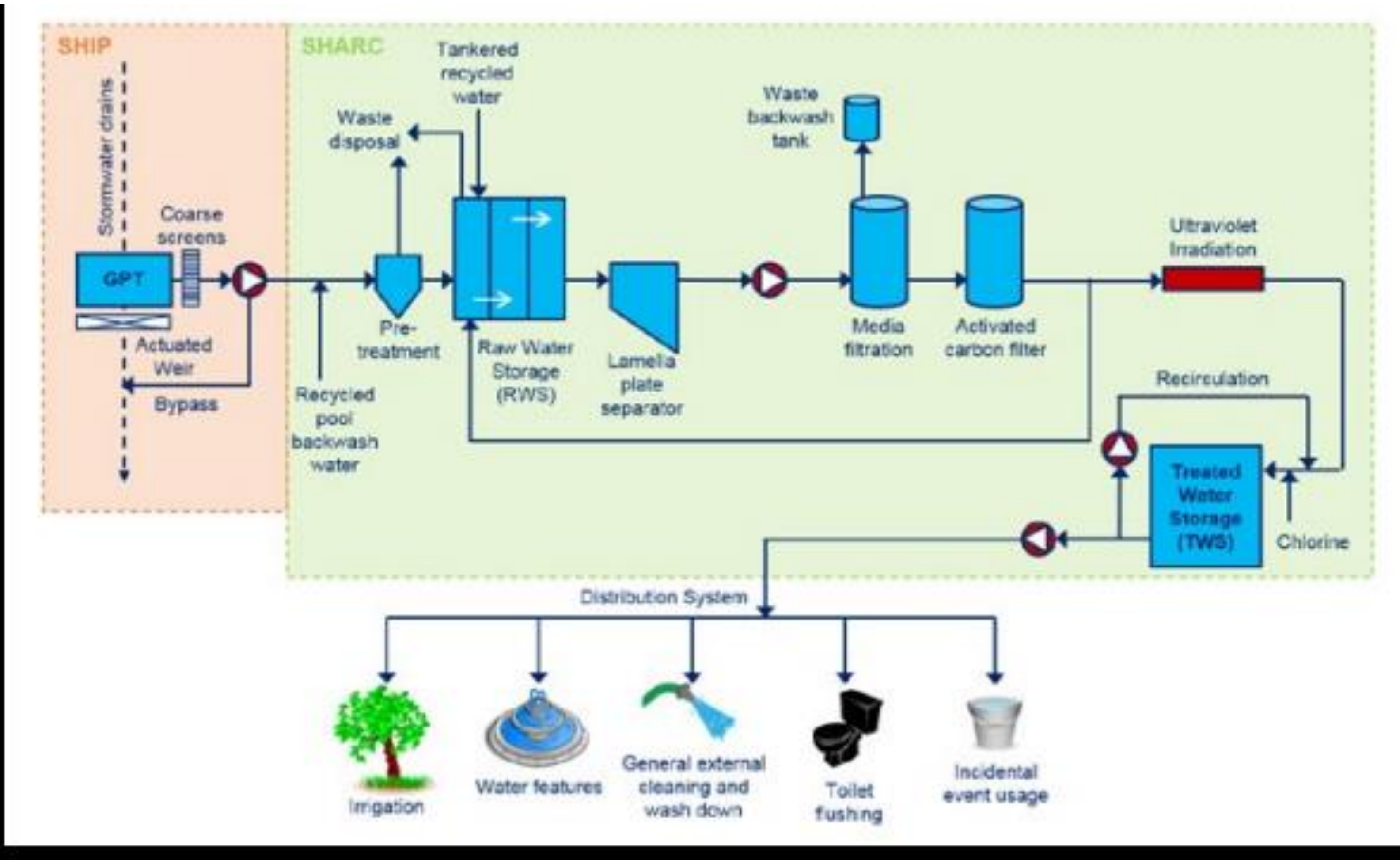


Figure6. Hydrograph for November and December

Finally, catchment infrastructure also plays an important role within the urban innovation process. Since there is intense economic activity in the area, it is necessary to understand the level of quality of water resources that can be harvested in the area. In particular, the biggest question was whether these resources could be used to irrigate vegetation without damaging it. Through an analysis conducted together with the Hazard Analysis and Critical Control point, four main areas of risk were identified: pollutants from roads, fumes and waste from possible fires, sewage overflows or failures, and saline river water entering the pipes. In order to overcome this issue, continuous monitoring was carried out during the first six months of operation to ensure that the water leaving the plant met a set of minimum hygiene standards, in accordance with the Australian Guidelines for Rainwater Harvesting and Reuse. Through a sensor located inside the SHIP device, it is possible to switch off the pumping system and prevent water from entering the storage tank. To enable the water to be treated correctly and effectively, a specific system was dosed and implemented, designed by the private company Stornoway. The system has several barriers on different levels and interacts with the SHIP device as shown in the figure below. In fact, the entire process starts with the latter: if the quantity and quality of the water meet the parameters (e.g. pH levels between 6 and 8.5), it is pumped into the raw water tank. Here, a pre-treatment activity takes place, in which part of the pollutants are removed, so as not to overload the system in the subsequent stages. The water then passes from the storage tank to the purification plant, represented in the green section and named SHARC. In a first round of treatment, coagulants are added to make the detection and subsequent removal of fine particles easier and simpler. Afterwards, solids remobilisation and sand filtration are performed to increase purity and reduce turbidity. The water passes through activated carbon filters, which are designed to remove any volatile organic compounds present in the stock. The final steps are the disinfection process: through the use of UV ultraviolet rays (primary disinfection) and the use of sodium hypochlorite, added in the form of liquid chlorine (secondary disinfection), all potential bacteria and viruses that may be present in the water are eliminated. Once this process is complete, the water is transported to the treated water storage to verify that the quality level meets the standards imposed by law. When this happens, the water is sent to the Distribution system and can then be used for a variety of non-potable usages such as agricultural use, water features and toilet flushing. The entire project cost $2.8M for the storage plant and $0.8M for the treatment plant. through the use of the Rain Bank, the City of Brisbane can convert 'waste' water into a valuable resource that can be fed back into the urban water cycle and reused by citizens. In fact, the system can purify more than 500 kL/day ehm and redirect it within the pips network to be readily reused. furthermore, the standards set by the Australian authorities regarding the minimum quality levels required have required. In addition, the standards imposed by the Australian authorities regarding minimum quality levels required an understanding of the water flows both into and out of the plant. By creating a purification process specifically designed for site conditions, you were able to take advantage of the use of standardised procedures, thus reducing the costs associated with implementing infrastructure that could have had little impact.[28]



CHAPTER 5

5.1 Conclusions and further indications

Observing and analysing what was said in that paper, a number of conclusions can be drawn on this issue. First of all, in the first chapter, we were able to observe and obtain an initial definition of what an intelligent city is. such a definition is fundamental and of great importance for several reasons. First of all, it is necessary to understand the type of urban layout we need, which must be characterised by the simultaneous presence of several factors: technological, political-institutional and social. They are the prime mover in stimulating change and above all in making it possible and transforming it into reality. consequently, in the absence of an understanding of these factors and in the absence of coordination between them to achieve superior results, every effort to significantly transform the urban structure in the medium/long term would be in vain. in addition, a detailed definition of the concept is also important to understand the different types of smart cities that can be manifested in the territory. In fact, according to the specific characteristics of each municipality, it is possible to find cities that are able to achieve superior performance in certain areas,9 such as an excellent transport system, a simple and streamlined process of participation in democratic life or an empowered community of citizens. therefore, through an initial definition of the smart city concept, it is possible to carry out an assessment of the initial position of our city, which resources and drivers are available to facilitate the transition and which (or which) city dimension will be favoured by the future urban structure (smart environment, smart governance, etc.). The presence or possible absence of such future arrangements plays a very important role within the water smart cities perspective. In fact, if, for example, a city already possesses the characteristics of smart mobility and smart environment, these can be exploited to facilitate and simplify the transition process towards a city sensitive to urban water management. However, some critical aspects of this concept should be noted. First of all, the lack of a universally shared definition of smart city (combined with the presence of a myriad of definitions that lack completeness and integration between its components) makes the concept very vague, vague and difficult to grasp, often limited to representing a futuristic and imaginary scenario, rather than oriented towards the adoption of concrete practices. In addition to this, there is also little public interest in the topic, as was demonstrated by a study of more than 400 smart-oriented initiatives29 , even though the urbanisation rates of cities and the number of their inhabitants are increasing, with a significant impact on the preservation of the environment and natural resources linked to the urban environment. Although it is acknowledged that it is impossible to provide a definition that can be valid for all cities, since each one has a different geographic, socio-economic and political-institutional profile, it is nonetheless necessary to emphasise the importance of being able to provide a point of reference that can be used by as many actors as possible. The final part of the first chapter also presents the main methods that can make such smart projects financially feasible, a fundamental factor that must always be taken into consideration when embarking on such projects, which often require the coordination of substantial public and private resources.

Having completed the phase of defining general concepts, we moved on in the second chapter to define the central theme of the research: water smart cities. To do this, it was first necessary to analyse and understand the natural water cycle on the one hand and the "artificial" water cycle on the other, generated by human activity through urban settlements. This distinction is useful for understanding how these two cycles interact and influence each other and, above all, what actions can be implemented so that the latter has a minimal impact on the former. Understanding the 'touchpoints' between the two cycles is crucial both for improving the quantity and quality of water resources that can be made available and for improving those that are released into the external environment, minimising their footprint. Next, there was an attempt by the author to offer an initial definition of what a Water Smart City is, which is often difficult if not impossible to find in the literature on the subject, unless the author illustrates his own. Although the concept of a water sensitive city has been around for a long time and has many similarities in common with water smart cities, it was nevertheless deemed necessary to identify the set of minimum necessary elements that form the necessary substrate of such projects, without which their realisation would be hindered or rendered completely impossible. They consist of the three pillars and the water smart city approach. The first, (i.e. Wastewater reduction and treatment, Sustainable water supply and Surface water runoff reduction and treatment) represent the ultimate goal to be achieved through the realisation of such projects, in order to achieve an urban scenario rich in high quality water resources and with reduced impact on the surrounding water resources. effective actions capable of guaranteeing these results will allow the city to benefit from improved hydric resources available to citizens, increased levels of urban visibility and minimal impact on the health of the natural water cycle. It should be noted, however, that a water smart city must pursue all three of these goals simultaneously, and it is clear from this analysis that practices that are aimed at achieving these goals and are often used separately and uncoordinated need to be integrated. to do this, it is necessary to develop a holistic approach to the issue of water resource management, which is defined in chapter two as the Water Smart City approach. based on theoretical research and empirical data available to date, it is based on three principles that represent the type of services a water smart city must be able to provide to its citizens. the three principles are: Cities as Water Supply Catchments, Cities providing Ecosystems Services, Cities comprising Water-sensitive Communities. Therefore, through the combination of these elements we have succeeded in arriving at an illustration of the Water Smart City concept. the second part of the chapter presents a conceptual framework that presents the steps through which a municipality must pass in order to become a Water Smart City. Thanks to this analysis, it is possible to assess at which "evolutionary stage" one's own city is, which water-related services it is already able to provide and which it cannot, and which it can still improve. This will also come in handy in the final part of Italy elaborated, where the business cases are analysed. Finally, the last part of the chapter presents a series of tips and suggestions that can simplify the urban transition process. They are presented by the CRCWSC, an Australian organisation that has been involved in the facilitation of all water sensitive practices for more than twenty years. the instructions presented in the paper are the result of all the field experience gained by the organisation over the years in one of the most advanced states in this field. In addition, the main obstacles to the implementation of smart projects are presented. An understanding of these elements is necessary to assess their possible presence within one's own urban scenario and to be able to implement practices to minimise their impact.

In the third chapter, the main methodologies and techniques through which a Water Smart City can be managed were presented. In particular, an analysis was first conducted on the historical trends concerning sustainability indexes, what the theoretical principles behind them are, and what we have been able to learn from the application of these tools over the last 20 years. This was followed by a presentation of the main water performance measurement tools that have been used in the past, together with their strengths and weaknesses. Thanks to the experience and knowledge accumulated through the use of the Arcadis Sustainable Cities Index and the City Resilience Index, a team of Australian researchers succeeded in proposing a new framework through which it is possible to quantify the level of 'water smartness' of a city. This tool is called the Water Sensitive City Index, and it is a tool that provides a benchmark of the city in question under multiple urban dimensions, all of which are related to the city's water resources to a greater or lesser extent. A set of good practices promoted by the CRCWSC is also proposed, in what might be called an iterative process in which key urban stakeholders meet in numerous workshops to assess the impact of already approved practices and discuss the possible implementation of further actions. Through the method proposed by the Australian research centre, a collective and collaborative process is generated in which the main actors in the change process meet and discuss frequently, stimulating a process of active participation by the community that is supported by the expertise of the advisors sent by the CRC to act as mediators. By using the Water Sensitive Index and the workshop-approach in combination, it is possible to define a clear and coherent roadmap of the steps that need to be taken to achieve a Water Smart City.

Finally, the fourth chapter presents interesting case studies that apply the techniques and methodologies presented in the second and especially the third chapter. In particular, the case studies concern the city of Sydney and the city of Bendigo in Australia. Through the use of the Water Sensitive Index it was possible for the researchers to assess the current state of the art of the two cities AND what actions need to be taken to move towards a water sensitive city. the analysis showed that Sydney is a very advanced city in terms of the adoption of water sensitive practices and Bendigo in this respect, is one of the most advanced cities in this respect. for this reason, Sydney is considered to be a 10% complete water smart city. the same kind of consideration can be made for the city of Bendigo, proving that if both cities continue on the path they are on, they will be able to complete their transformation process within a few years. This consideration is even more important if we consider that Bendigo is a city with a mining-related Legacy, which historically has marked the surrounding natural environment. However, through this new change of direction, the city's future looks more positive and prosperous. this example is therefore of great importance for all those cities and urban settings that are profoundly influenced by local or surrounding economic activity and shows us that even in situations where the natural environment and hydric resources are degraded due to past activity, it is still possible to implement new actions that can counteract and even reverse this trend. Finally, the final part of chapter four presents specific solutions that have been adopted in two cities: Brisbane and Lyndhurst. These examples are useful to concretise and make tangible what was stated in the previous chapters of the paper, through the presentation of concrete solutions whose performance can be evaluated. Furthermore, the case study of Aquarevo and the Rain Bank was presented because it is characterised by great scalability: if for example we imagine applying such solutions in our city, the benefits obtainable in terms of the preservation and improvement of urban water resources are evident. such innovations make it possible, on the one hand, to collect large quantities of rainwater that falls within urban spaces, to make it available to citizens, and the other to build and manage homes that minimise the waste of water resources while maximising their recycling and reuse. If we imagine a municipality that applies these two solutions in an integrated manner, it follows that it is possible to achieve superior benefits due to the synergies established between these practices. Through such work, it is therefore possible for a public decision maker interested in the issue to begin the process of urban change and transition. In the opinion of the author of this paper, the topic of water smart cities is still being unjustly and unduly ignored by public opinion, despite the fact that the effect produced by climate change is now evident to all, as demonstrated by the problems caused by the drought in the Po Valley and the consequences it is causing: the lowering of the main rivers, a significantly reduced level of the main lakes and catchment areas, with heavy consequences for the agricultural industry and livestock farms in the comma area, which have suffered billions of euros in damage in the last year. Considering the Italian case in particular (but this reflection can be developed for all the cities of the world), the probable anomalous heat wave forecast for next summer will bring to the centre of the debate the issues presented in this comma paper, which it is hoped will represent an interesting and stimulating starting point for sustainable change in the medium to long term.

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IMAGES AND CHARTS:

- **1st and 3rd image:** file:///C:/Users/mw/Downloads/smartcities-05-00050%20(1).pdf
- **2nd image:** The concept of 'smart city': dimensions, characteristics and models**,** Pozdniakova A.M., Research Centre of Industrial Problems of Development of NAS of Ukraine; Kharkiv, Ukraine
- **4th, 5th and 6th images:** https://www.oecd.org/cfe/cities/OECD_Policy_Paper_Smart_Cities_and_Inclusive_Growth.pdf
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- **9th and 10th images:** https://www.iwra.org/wp-content/uploads/2022/02/Smart-Water-Cities-report-Part-1.pdf
- **11th image:** https://edepot.wur.nl/407327
- **12th and 13th images:** Transforming Cities through Water-Sensitive Principles and Practices, Tony H.F. Wong, Briony C. Rogers, and Rebekah R. Brown
- **14th image:** Sustainability indicators and indices: an overview, *Jianguo Wu*
- **15th image:** 2022 Arcadis Sustainable Cities Index, *John Batten*
- **16th, 17th,18th, 19th, 20th and 21st images:** *Water Sensitive Cities Index: A diagnostic tool to assess water sensitivity and guide management actions, Rogers, Dunn, Hammer, Novalia.*
- **22nd, 23rd, 24th, 25th and 26th images:** South East Water Annual Report 2021-2022

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2. **Global Trends of Smart Cities:** *A Comparative Analysis of Geography, City Size, Governance, and Urban Planning*
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