AALBORG UNIVERSITY
STUDENT REPORT

Enhancing urban environmental sustainability with the hosting of Olympic Games:

reality or dream?

Master Thesis

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Summary

Olympic Games are sporting mega-events occurring in a different city every four years. Negative economic, social and environmental impacts from the staging of the Games led in the middle of the 1990's to the creation of a new model for the Olympic Games based on the concept of sustainability by the International Olympic Committee, the main international non-governmental organisation owner of the Games. Since then, a growing integration of new practices and knowledge towards the implementation of the concept of sustainability in the planning, preparation and staging of the Games has been experienced. Part of those new practices are the new sustainability tools used by the organisers of the Games. Despite those new practices, the Games still entail negative environmental impacts. Yet, the Olympic Games also play a positive role in the urban development of the city. The review of the existing literature shows that the relation between environmental sustainability and Olympic Games is still at an early stage of research. This project thus examines the role of the Olympic Games in the development of the environmental sustainability in the host city.

First, the existing sustainability tools used during the planning of the Games are analysed. Even though the application of those tools promotes the development of new practices towards sustainability within the practices of the Games' organisers, they do not ensure the staging of sustainable Olympic Games. Their methodological limitations reduce their impact on decision making towards sustainability. Besides, those tools do not provide any guidelines nor good practices to be implemented by the Games' organisers to enhance the environmental sustainability and thus reduce the negative impacts.

In order to further understand the dynamics of the Olympic Games towards environmental sustainability, the example of the water sector is used, and especially how the Olympic Games impact the water sustainability in the host city. By using a multi-case study on three different Olympic Games - Beijing 2008, London 2012 and Rio 2016 - this project presents the main responses taken during the preparation of the Games towards water sustainability and their efficiency. Those responses are divided into three main challenges related to water: water quality, water availability and climate change. The Driver-Pressure-State-Impact-Response is used as an analytical framework in order to frame the structure of the analysis, and to further understand the specific target of each type of response. Based on those responses and the analysis of the underlying dynamics, some initiatives towards more sustainable practices are recommended both to the Games' organisers and to the International Olympic Committee. Those initiatives for instance include the setting of specific sustainability requirements or the releasing of specific quantitative data regarding environmental sustainability in order to increase the transparency of the Organising Committees.

Overall, regarding the water sector, the Olympic Games act as a tool for developing new and modern water-related infrastructures in the host city, are an accelerator for existing sustainability development plans and are an innovation lab for new sustainable practices. Those findings are all related to the water sector, but can be generalized to some extent to the other sustainability dimensions such as transport, water or energy. This way, the Olympic Games can enhance the environmental sustainability in the host city. Yet, the positive impacts of the Olympic Games on the environmental sustainability of the host city are still limited by, for instance, mismanagement or the prioritisation of other prevailing aspects. There is thus a need for the stakeholders of the Olympic movement to engage in a more transparent and meaningful way towards the integration of the environmental sustainability concept within all their practices.

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1 Introduction

The Summer Olympic Games are the world's main sporting mega-events, occurring every four years in one city or region around the world. Those events gather thousands of athletes and spectators from all around the world. During the Games, many systems of the city, such as the waste management, the energy supply, the transport, the water supply, or the city's accommodation stock are pressured, and the city must accommodate those systems to the specific needs of the Games and the growing number of people living in the city for a very short period of time.

In parallel, cities must deal with other challenges. First, urbanization is a global trend around the world, as it is expected that 68% of the population will live in cities 2050, compared to 55% in 2018 (United Nations, 2018). Besides, the impacts of climate change threaten cities, with a rising number and intensity of extreme events. Advancing urbanization in combination with increasing vulnerability towards climate change stress the need to develop sustainable cities.

The concept of sustainable development has been, for decades, one of the main focus of the urban discussion. This concept is currently considered as relatively established, as one definition for sustainability has been widely used since the Brundtland Commission: the ability to "meet the needs of the present without compromising the ability of future generations to meet their own needs" (World Commission on Environment and Development, 1987, p16). Three pillars are often used to describe the concept: the social, the environmental and the economic. This concept is highly discussed and integrated in the strategies of many companies and organisation. This is the case for the International Olympic Committee, which integrated this the environmental dimension as the third dimension of the Olympic Movement. At first sight, the integration of the concept of sustainability could appear as nonsense, because it contradicts with the concept of the Games. During the Olympic Games, there is a concentration of investments and people in time and space, while sustainable development suggests the dispersion of investments in time and space (Furrer, 2002). The Olympic Games further pressure the environment with a concentration of new infrastructures in few places across the cities.

Hosting the Olympic Games is nonetheless a strategy for urban regeneration because it justifies the enhancement and redevelopment of urban areas. In fact, mega-events are often considered as accelerators for major urban transformation or renewal projects (Essex and Chalkley, 1998). For instance, major events can boost wider urban regeneration project by extending or accelerating existing plans. As well, mega-events are increasingly used to showcase sustainable urban development. Therefore, in this project, the Games are considered as both having adverse impacts on the environment, that should be mitigated, but also act as an opportunity to enhance the urban environment of the host city.

Rising awareness over the negative environmental impacts of the Games by local inhabitants and non-governmental organisations, as well as a public reluctance for hosting the Games due to their high costs have called the International Olympic Committee for the development of a new model for Olympic Games in the middle of the 1990's (Furrer, 2002). Besides, this model is a response to the decreasing number of cities willing to host the Games, for fear of building mega infrastructures with non-futuristic projects of use after the Games. In fact, one of the main issues regarding the Olympic Games is that some the infrastructures built for the Games, including sport venues and Olympic Village, are left abandoned and completely unused after the Games, because of lack of public demand or maintenance (Davis, 2019).

This model relies on the integration of the concept of sustainability in all the practices of the Olympic movement, including the ones from the Games' organisers. Overall, this new model should enhance the benefits and reduce the economic, environmental and social impacts related to the Games. Additionally, the model promotes long-term legacies over short-term investments, especially in order to reduce the number of unused infrastructures after the Games. This new model has been developed since the 2000 Games in Sydney, which were considered as the first "sustainable" Olympic Games (Weiler and Mohan, 2010). Since then, all the host cities have tried to design Games in a more sustainable way (Konstantaki, 2018), developing new practices and using different environmental evaluation tools to enhance the sustainability of the Games. Besides, the Games' organisers have started to integrate the concept of legacy in the bid process by selecting the cities that best consider the incorporation of the Games in their urban development policies (Abebe et al., 2014).

Despite the implementation of this new model and the use of sustainability assessment tools, there are still negative impacts and mismanagement during the Games. For instance, the last Summer Games in Rio were heavily criticized because of the water quality of the venues for the sailing competition, as it was considered by some too polluted to ensure a safe and healthy bathing quality (The Guardian, 2015). Likely, during the Games in Beijing in 2008, an algae outbreak occurred at the Olympic sailing venue (UNEP, 2009). Those two situations raised a debate among non-governmental organisations and citizens on the difficulty of Games' organisers and host cities to fulfill some of the environmental commitments made during the planning of the Games. Those two examples deal with the water issues, yet other examples of unfulfilled commitment can be found for other environmental sustainability dimensions (e.g. energy, transportation, waste).

This project specifically focuses on the issue of water sustainability and Olympic Games. First, from a methodological perspective, this focus intends to limit the scope of the project, and water should then be considered only as an example of how the Olympic Games impact the environmental sustainability of the host city. Then, this issue was as well chosen because no paper in the existing literature has specifically focused on the relation between Olympic Games and water management in the host cities. No paper really calls for the analysis of the relation between water sustainability and Olympic Games. Yet, it does not mean that this relation should be overlooked. The two practical examples presented above on Beijing and Rio show that this issue is still problematic during the Olympic Games. Moreover, the growing challenges of cities towards decreasing water resources and the fact that Olympic Games are held during the summer month, so when the demand for water is the highest, highlight this need to start a discussion on water sustainability and Olympic Games.

A part of the urban sustainable development is the management of natural resources, such as water resources. In fact, urbanized areas concentrate the demand for water. Water sustainability comprises different challenges, including the water supply and access to sanitation which is a global target around the world. In fact, the Sustainable Development Goals include one goal towards clean water and sanitation: "ensure availability and sustainable management of water and sanitation for all" (United Nations, 2016, p20). As mentioned before, the Games can act as catalyst for urban development, and thus be used as a response to enhance water sustainability of cities. But in order to strengthen even more the benefits and reduce the still existing negative impacts, it is essential to know the types of response, and the main technological and governance issues met in their implementation.

The aim of the project is thus to perform a qualitative investigation and analyse if and how, through the hosting of the Games, the environmental sustainability of the host can be enhanced by specifically focusing on the water sustainability dimension.

Research question

The following main research question is considered throughout the report:

What roles do the Olympic Games play in the environmental sustainability of the host city?

To answer this main research question, three sub-question are specifically examined:

- What are the existing sustainability assessment tools used during the planning and preparation of the Games and what are their limits?

- What are the current Olympic Games responses related to urban water sustainability and how efficient are those responses?

- Which initiatives are to be recommended for future Olympic Games and the International Olympic Committee to enhance environmental sustainability of cities and reduce the negative environmental impacts?

The first chapter of this report sets the context of the project, with information about the Olympic Games, the evolution of their impacts on the environment, but also their governance. The second chapter presents and shows the limits of the existing literature on the relation between environmental sustainability and Olympic Games. The third chapter deals with the analytical framework, the Driver-Pressure-State-Impact-Response approach that is used to structure the analysis. The next chapter explains the research design, a multi-case study, the scope of the project and methods used for this project. Then, the existing sustainability assessment tools for Olympic Games are presented in order to highlight their limit, and to show why they do no ensure the staging of sustainable Olympic Games.This further help understand the need to provide effective new practices and initiatives for future Olympic Games to enhance their sustainability. The fifth chapter displays the main findings, by first presenting the cases analysed and the main responses towards water sustainability. The identification of the main measures and responses provides useful insights on whether those measures are useful and successful. This leads to the proposition of possible initiatives to guide future Games organisers to increase sustainable management of water resources both during the Games and in long term. Finally, the last chapter discusses the results and limits of the project, and likewise examines the relation between sustainability and Olympic Games.

2 Contextual Framework

This chapter provides information on the Olympic Games, in order to set the contextual framework of the project. It mainly includes knowledge on the Games, with first an historical review of the motives of cities behind the hosting of the Games. The understanding of the urban context in which the Games occur is important for the understanding of the project. Then, a review of the main stakeholders of the Olympic Games, their relations and a description of the planning process of the Games is carried out.

2.1 History of the Olympic Games

During the last few decades, the reasons for hosting the Games have evolved. The following parts dive into the development of Olympic Games, and how they have become a worldwide event. Besides, those parts present the types (economic, social, environmental spatial and governance) of motives and how the strategies have changed throughout the 20th century.

2.1.1 From a sporting event to a strategy of urban regeneration: 1896-1972

The modern Olympics were initiated by Pierre de Coubertin in 1896, under the motives that sport could promote physical renewal but also cultural revival (Gordon, 1983). Until 1960, the reasons for hosting the Games were mostly limited to sportive ones. One exception was for the Games in Berlin in 1936, when the political motives were prevailing over sporting ones (Essex and Chalkley, 1998). The impacts on the urban environment were lessened first to new sports infrastructures, then to an Olympic quarter in the city (Liao and Pitts, 2006).

Then, until 1984, the Games were used to develop and especially modernize the urban environment. The Games were considered as stimulating the urban regeneration and economic development (Kitchen, 1996). In 1960 (Rome) and 1964 (Tokyo), the cities used the Games to improve the urban environment through important regeneration projects. These projects include the development of new and modern infrastructures such as better public transport or new airport facilities. Especially, those two cities built new water systems (Liao and Pitts, 2006). The main reasons for those two cities to host the Olympic Games was to benefit from the economic dynamic behind the Games to modernize the cities.

For the Games in Munich (1972) and Montreal (1976), spatial development was the main reason to host the Games, with the development of already existing city plans. The Games, in those cases, were used to speed up the implementation of those plans (Essex and Chalkley, 1998).

2.1.2 A new paradigm: 1976-1992

Even if the Games in Montreal led to the improvement and renovation of many city infrastructures, the costs associated were too high, leaving the city with an enormous debt. A striking example is the building of the Olympic Stadium which cost $1.5 billion and still costs every year in maintenance $32million. It took 30 years for taxpayers to pay it off (Weiler and Mohan, 2010). Those types of huge infrastructure, that are an economic loss for cities are called "white elephant", and are still one of the main challenges in modern Olympics. To avoid such economic losses, the Games in Moscow in 1980 favoured the use of existing infrastructures.

In 1984, Los Angeles had to deal with the unwillingness of taxpayers to pay for the Games, so those Games were privately funded. This was an important shift in the economic model of the Games (Weiler and Mohan, 2010). First, the International Olympic Committee wanted to refuse those privately funded Games, but as Los Angeles was the only city bidding for the 1984 Games, the IOC did not have the choice but to accept the bid, due to the lack of other alternatives. This absence of other cities bidding for the Games was due to the negative impacts and political events of the previous Games: political protests in Mexico in 1968, terrorists attacks against Israeli Olympians in Munich in 1972, the debt of the Games in Montreal in 1976 and the boycott of the Games in Moscow in 1980 (Essex and Chalkley, 1998).

To face this unwillingness to pay and to avoid the economic disaster of the Games in Montreal, the Los Angeles Organising Committee required that Olympic sponsors and multinational corporations should pay for a larger share of the costs. Consequently, few infrastructures were built and many already existing facilities were widely used. This led to a financial success, with $225 million of operating surplus. Those Games are often characterized as a turning point of the Olympic Games (Weiler and Mohan, 2010). Afterwards, cities and countries started to realise the importance of economic benefits of the Games and a growing number of bids was noticed after those Games. The motive behind a candidature was, among all, economic reason. For the Games in Barcelona, back in 1992, an economic crisis was affected the city during the bid process back in the early 1980's. Games were seen as catalyst of both short and long term economic growth, and therefore considered as a tool to reduce the impacts of this economic crisis (Gratton and Preuss, 2008). Especially, the Games enhanced the international prestige of the city and improved its competitiveness. This led to a rise by 31% of tourists coming to visit the city after the Games, compare to the situation prior to the Games (Sananhuja, 2002). Thus, the Games really brought long-term economic benefits to the City.

2.1.3 Recent Games: 1992-2020

Up to 1992, using the Games to improve the urban environment of the host city has almost always been one motive to host the Games, maybe apart from the Games in Los Angeles. To go even further, the Games in 1992 in Barcelona addressed the social aspects of the Games, through enhancing the social integration by improving low quality neighbourhoods and providing sport facilities in those areas. The largest park of the city was used for the Games, and was redeveloped and refurbished (Garcia-Ramon and Albet, 2000). Since those Games, there was a transition in the development strategies of host cities which before focused on the construction of massive sport and urban infrastructures, and which is now more focused on a broader notion of urban regeneration. Atlanta (1996), Sydney (2000) and London (2012) built their Olympic Parks on contaminated sites, Athens (2004) built it on a former military base (Liao and Pitts, 2006).

The main motives behind the Games in Sydney in 2000 was to internationalize Australia and to promote international tourism (Chen et al., 2013). For Beijing 2008, the motives were several: to showcase the country, to show that China is very capable to host such mega-event and to enhance China and Beijing redevelopment (Zhou et al., 2012). For London, in 2012, one of the main motives, as mentioned by the former mayor of London, was that hosting the Games would create an opportunity to get more money from the government to develop new infrastructures in the city (Chen et al., 2013). Rio had the same motives as Barcelona, back in 1992, as Rio wanted to improve the infrastructure (transport, waste) and improve the prestige of the city to attract international tourists (Gaffney, 2010).

2.1.4 Overview of the motives behind the Games

The motives for hosting the Games have evolved through history. The economic motives, which have prevailed, include the restructuring of the local economy like for Barcelona in 1992, the improvement of city's competitiveness and the development of a new image to promote international competitiveness, and city branding, as in Sydney in 2000. In terms of spatial motives, the improvement of urban infrastructures and regeneration of some areas are among the most important, such as in 1960 and 1964 and Rome and Tokyo. For Barcelona, Atlanta, Sydney, Athens and London, a strong focus was put on a regeneration of a specific area of the city. Beijing and Rio were more into a general development of the city with the improvement and development of new infrastructures (public transport, water and waste systems). An important issue raised by this historical review is that there are never been any environmental reasons as main motives for hosting mega-event.

2.2 Games' design

This section presents the actors and stakeholders of the Games. It then dives more specifically into the explanation of the bid process and planning of the Games, from a governance perspective.

2.2.1 Stakeholders and governance of the Olympic Games

The Organising Committee of Olympic Games (OCOG) is the main organisation responsible for planning, preparing and staging the Olympic Games. At each Olympiad, the National Olympic Committee (NOC) of the host country and the government of the host city establish an OCOG, which then must follow the requirements from the International Olympic Committee (IOC). The IOC is the owner of the Olympic Games, and the leader of the Olympic Movement. This non-governmental organisation is responsible for ensuring the staging Summer and Winter Games, and selecting the host cities. Finally, another actor is the Olympic Delivery Authority (ODA) which is a public entity created by the OCOG to coordinate the work of the national, regional and municipal governments in the provision and operation of the infrastructures needed for the Games. Those actors are the main ones considered in this project, but many other important stakeholders are involved in the staging and preparation of the Games, such as the sponsors, and the international federations.

Figure 1 shows the main stakeholders of the Olympic Games, and their relations. The coloured circles highlight the main actors that have an important role in this project, and that are widely discussed: the International Olympic Committee (IOC), the Organising Committee for Olympic Games (OCOG), the local governments, the Olympic Delivery Authority (ODA) and the non-governmental organisations. The term Games' organisers that is used along this report groups the OCOG, the local governments and the ODA. The environmental non-governmental organisations, such as Greenpeace or WWF, are important stakeholders for this project as well. They play the role of external observers of all the environmental practices of the Games' organisers and their impacts. They also sometimes work in collaboration with the organisers to help them set the environmental strategies and objectives.

2.2.2 Governance of the Games

The concept of governance deals with the organisation of decision-making processes. It is important to understand those for the Olympic Games, because they are different from normal urban planning processes. This part presents some of the main governance processes that are important to be aware of for this project.
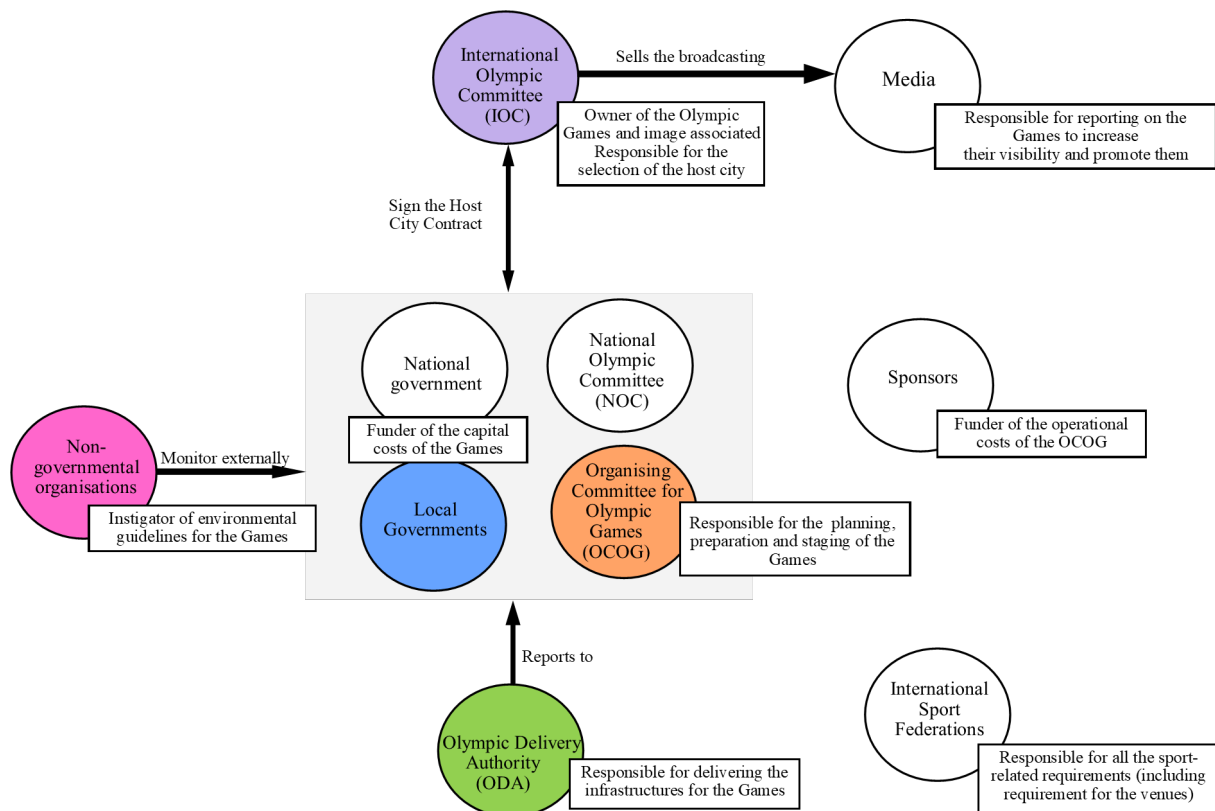
Figure 1: Stakeholders of the Games

Bid process

The bid for the Olympic Games is a long process taking several years and involving different candidate cities that are in competition. Each candidate city must first have the support from their respective National Olympic Committee. Then, a specific company, often called "City + Year of the Games" (e.g. London 2012, Rio 2016) is created to take care of the bid procedure. This company is responsible to get the support from important stakeholders for the Games, such as the local governments, the national one and other important organisations. This support is essential in order to make the bid stronger, and to ensure that the local and national governments will be financially involved in the Games. During the bid, this company is further responsible for preparing a master plan representing the overall design of the Games, which is made in collaboration with the local governments. The choice of venues, new infrastructures, development plan and sustainability commitments are determined by discussions between the company, the national, regional and municipal governments and the owners of the existing infrastructures.

The growing public expectation for more responsible Olympic Games, in terms of social, economic and environmental impacts (Weiler and Mohan, 2010), combined with the mandatory inclusion of the concept of sustainability in the bid, lead to the introduction of new principles and practices in the bid of the candidate cities, in order for their application files to appear stronger and innovative.

Preparation and staging of the Games

Once the bid is won, a new company is created: the Organising Committee for Olympic Games (OCOG). There is some knowledge transfer sessions between the company created for the bid and the OCOG, which is responsible for the implementation of the plan, the staging of the Games and the wrap-up. The knowledge transfer is essential in order for the OCOG to fully understand the details of the master plan and the overall strategies behind the Games. The OCOG signs the Host City Contract along with the local government, the NOC and the IOC, as shown in figure 1. This contract sets all the mandatory technical requirements for the Games, and makes the OCOG legally responsible for the staging of the Games.

The preparation for the Olympic Games is different from usual planning procedure, because there is only seven years between the end of the bid process and the staging of the Games. First, two years are often needed to refine the master plan, to buy the lands needed for the new infrastructures and to relocate the businesses and inhabitants living in those lands. It is the Organising Committee for the Olympic Games which decides the operational strategies, which must comply with the bit commitment. The next five years are used for the construction. Any delay in the building of infrastructure cannot be accepted, so most of the time the planning procedures are accelerated, and even overlooked. Finally, the Games are held for a two weeks period during Summer.

Regarding the sustainability commitments, the Host City Contract does not provide any sustainability objectives. It is the OCOG which is the main actor responsible for the environmental management during the preparation and staging of the Games. One of the key driver to integrate environmental sustainability in the design of the Games is the strong relation between OCOG and non-governmental organisations starting at an early stage of the project (Greenpeace, 2008; Weiler and Mohan, 2010).

Knowledge transfer program

A Knowledge Transfer Program was developed by the International Olympic Committee after the Games in Sydney back in 2000. The Organising Committee in Sydney realised the value of knowledge and information, first internally inside their organisation and to future Organising Committees (Parent et al., 2014). The main elements of this program include the sharing of services, information and personal experiences. Samuel and Stubbs (2013) show that knowledge transferred can bring value to the staging of the Games. According to them, it is important to learn from the past Games and the reporting made throughout the preparation of the Games is one way forwards. This program also enables the diffusion of best practices (Vanwynsberghe, 2015).

This program occurs at different stage. First, during the bid process when the overall design of the Games is determined, the candidate cities have access to technical reports, can participate to workshops and can have discussions with experts with hands-on experienced. One issue is that the knowledge accessible to candidate cities and to the Organising Committees is filtered by the IOC. This entails a design and planning of Olympic Games shaped by the same group of elitist stakeholders (Kassens-Noor, 2019), and thus increasing similarities between the Games, without consideration of the specificity of each local context.

This program received other critics (Stewart, 2012). First, the fact that the Games only occur every four years makes it difficult to identify best practices, especially when the technological context evolves rapidly. Another issue is that the competition between the different Organising Committees creates reluctance to share their knowledge. Finally, the financial costs of knowledge sharing can impede the Committees to really invest on it. In fact, those Committees prefer to invest in the gathering of knowledge for a future even host in the city. Overall, Stewart (2012) concludes that Olympic Games do not need knowledge transfer but a total transparency.

The numerous limitations of this knowledge program and the lack of evidence on whether it really helped some Games' organisers highlight the need to develop a new model for knowledge sharing and organisation learning. Also, nothing was found on the types of knowledge that are shared - is it only on technical issues, does it include anything on environmental sustainability? Thus, if Games organisers and the IOC cannot ensure proper knowledge sharing, it is then the role of other actors, including researchers, to analyse and recommend best practices and positive dynamics towards sustainability.

3 State-of-the-art: Environmental Sustainability and Olympic Games

This chapter presents the existing literature on the environmental sustainability and Olympic Games. Around 40 research and review articles, written from the end of the 1990's to current days, were found during the project. Those articles come from different type of journals - planning, scientific, social science, environmental,management, sport & tourism - with an overrepresentation of articles coming from journals on event, sport or leisure. The relation between the environmental sustainability and Olympic Games is thus studied by a mix of disciplines. In the chapter, this literature review is divided into five main topics of research in which most of the papers found fall within: the history of sustainability and Olympic Games, the environmental impacts, the Games and urban development, the legacy of Olympic Games and finally the critics towards the possibility of creating sustainable Olympic Games. Those five topics were identified during the project, when the different papers were reviewed. For reasons of clarity and understanding, the following sections each represent one topic.

3.1 History of sustainability and Olympic Games

The history of the relation between sustainability and Olympic Games has been widely qualitatively reviewed by many different authors. Especially, an important focus is given to the concept environmental sustainability, the historical integration of environmentalism in the Olympic Movement and the greening of the Olympic Games (Cantelon and Letters, 2000; Weiler and Mohan, 2010; Samuel and Stubbs, 2013; Gold and Gold, 2013; Krieger and Langenbach, 2018; Ross and Leopkey, 2017). It is the most studied topic among the five identified above, and most of the papers having this specific approach are published in academic journals related to sports or events. The objective of almost all those papers is to provide an historical analysis how the concept of sustainability emerged within the Olympic Movement and what were the reasons for it, starting back at the beginning of the 1990's until the beginning of the 2000's.

It was in 1992, during the Winter Games in Albertville, that the negative environmental impacts of the Games were for the first time publicly denounced. Among others impacts, the destruction of biodiversity and alpine environment to build ski runs, the storage and use of ammonia to refrigerate the bobsleigh track raised many protests from the inhabitants of the city (Cantelon and Letters, 2000). In order to reduce this controversy and to restore a positive image of the Games, the International Olympic Committee decided to introduce the concept of sustainability in the Olympic Charter in 1994. The participation of the IOC in the Rio Summit back in 1992 was as well a driving factor for the inclusion of the sustainability concept as the third pillar of the Olympic Movement (Weiler and Mohan, 2010). Following this integration, the IOC developed in 1999 an Agenda 21 for the Olympic called *Olympic Movement's agenda 21 for Sustainable Development*, based on the Agenda 21 of the United Nations (Krieger and Langenbach, 2018). This Agenda aims at promoting sustainable development, especially the improvement of socio-economic conditions and the sustainable management and conservation of resources in the Olympic Movement (IOC, 1999). Then, Sydney in 2000 was the first Games to include the concept of sustainability in their bid (Samuel and Stubbs, 2013). After the Games in Sydney, the IOC decided to make the concept of sustainability and environment mandatory to integrate in the bid process.

An interesting point that was identified is that the shaping of the sustainable and environmental policy of the IOC mainly derives from the impacts of Games - such as the negative impacts in Albertville in 1992 - or by the innovative initiatives taken by Games' organisers - such as the integration of the concept of sustainability within the bid process after the Games in Sydney (Guthoff, 2016). Three main phases regarding the integration of environmental themes within the Olympic Games was identified: first, the environment, then sustainability and finally zero-impacts (Ross and Leopkey, 2017). The concept of zero-impact Games started with London 2012, the first Games which have tried to go for climate neutrality and zero-waste.

3.2   Environmental impacts of the Games

Similarly, the different environmental impacts of the Games are widely investigated, both qualitatively and quantitatively. Different ways of studying the impacts of the Games were identified during the literature review. First, the focus of the paper is on one specific Games and a review of the economic, social and environmental impacts is performed. The other alternative is to focus on multiple Games, and a review of one specific type of impact is performed. Another way to is to analyse the impacts of the Games on one specific environmental sustainability dimension - transportation, buildings, waste, air quality. Each of the following paragraphs presents one specific approach.

Tziralis et al. (2008) focused on the Games in Athens, and quantitatively reviewed the economic and environmental impacts, with the analysis of the evolution of specific quantitative data (e.g. concentration levels of a fine particles in the city from 1996 to 2005). Their study only includes the impacts of the Games on the transport sector and the air pollution. They found that the Games in Athens had positive impacts on the development of the transport network. On the other hand, the levels of pollution in the city started to rise around four years before the Games, and this was attributed to all the construction works going on at that period for the building of the infrastructures for the Games. This way, the Games had negative impacts on the air quality of the city, especially during the preparation for the Games (Tziralis et al., 2008). Gaffney (2013) presented some of the negative environmental impacts of the Games in Rio, and the dynamics behind them. For instance, the construction of the golf course is given as a striking example of how the Games negatively impact the biodiversity. This construction was conducted on a protected area, one of the few wetland space remaining in the city and was possible by a legal change made by the local government of the zoning of the area, making it not a protected zone anymore. This was justified by the fact that the area had already been altered by anthropogenic activities, and that the building of a golf course brings more legacy than protecting the existing natural environment (Gaffney, 2013). This example shows how the local governments can modify their existing laws to build the new infrastructures where they want and by doing so they can indirectly enhance the negative impacts of the Games on the environment.

Guthoff (2016) made a qualitative review of the positive and negative impacts of four Games, Albertville 1992, Lillehammer 1994, Sydney 2000 and Rio 2016. Building on the review of these impacts, some policies to be implemented by the IOC to reduce the negative impacts and enhance the positive ones are proposed. Those policies include the implementation of best management practices regarding environmental challenges and the leading of independent environmental audits by external stakeholders in order to avoid any misrepresentation and bias from the Organisers of the Games (Guthoff, 2016).

Finally, many papers also deal with the analysis of one specific dimension of the environmental sustainability, and how the staging of the Games negatively or positively impacts this sustainability dimension. Those papers are mostly found in scientific journals which subjects depend on the sustainability dimension studied. One of the most widely studied environmental dimension is the air quality. This is especially analysed in Beijing (Chen et al., 2013; Wang et al., 2010) or in Rio (De La Cruz et al., 2019). In Beijing, the different studies found that the Games had a positive impact on air pollution, with a reduction of the pollutant's concentration during the Games, but with the levels of pollution returning to the ones prior to the Games afterwards. The impact of the Games on the transportation sector has been widely discussed by Hensher and Brewer (2002), Zhou et al. (2010) and Kassens-Noor (2013). The main outputs of those studies are that the Games have positive impacts on the development of transport network, with a focus evolving from the expansion of the road networks for older Games to the development of public transport in the most previous Games. Other studies focus on the building sector (Maloutas et al., 2009), or on the waste sector (Douglas, 2011).

3.3 Games and urban development

The relation between Olympic Games and urban development is also examined. The papers on this specific topic are mostly found in planning journals, and written by researchers in urban planning or geography. This subject is widely studied in the existing literature. It is analysed in the literature with mainly one specific angle, which is the analysis of several Games, or several mega-events, including one Olympic Games and how those events shape urban development.

Rijina and Sujith (2019) analysed three mega-events, including one Olympic Games. They only qualitatively examined the positive outputs of those events on the urban environment. They shown that mega-events have the capacity to boost the efforts of the city to improve its infrastructure, transport system and economy (Rijina and Sujith, 2019). Essex and Chalkley (1998, 1999) reviewed the effects of the Olympic Games on the physical environment, through an historical timelines and qualitative presentation of different Olympic Games. They show that there is a growing use of the Games as a tool for urban improvement, accelerator of existing plan and to stimulate the development of new infrastructures. This development is also linked with the fact that there is a rising media coverage and the city being shown off. The financial investments made during the Games are directly linked with the amount of urban infrastructures that are modernized or built during the Games. This show an inherent relation between the cost of the Games and the urban development in the city.

Liao and Pitts (2006) made an historical review of the urban patterns related to the Olympic Games, similar to the study from Essex and Chalkley (1998). Their main contribution is the creation of theoretical models representing the Olympic Site integration in the host city, based on empirical investigations and analysis of different Games. In addition, they provide some of the key factor of success of Olympic Games, such as the need for the Olympic Scheme to be part of a holistic plan (Liao and Pitts, 2006). Lauermann (2014) made a study on the impact of a failed bid on the urban development by studying the bid of multiple Games, and shown that even when it fails, bidding for the Games brings a positive legacy for urban development in the candidate city. This is possible because the bidding leads to the development and formulation of a local planning strategies, that are, to some degree, often implemented.

The relation between Olympic Games and urban development is further studied by only looking at one specific Games, such as Sydney (Searle, 2012) and London (Poynter et al., 2015). In Rio, many different authors shown that the urban development strategies of the city in the last 20 years was based on the staging of mega-events, and this led to an exclusive urban development and regeneration only shaped by elites group (Sánchez and Broudehoux, 2013; Gaffney, 2010; Schwambach, 2012)

3.4   Legacy of the Games

Another studied topic related to the Olympic Games is the issue of legacy, which has not yet been extensively studied. Most of the papers dealing with this specific topic are published in sport-related academic journals. This concept deals with the long-term impacts, of many different kinds, of the Games. Different definitions were proposed for this concept but there is not yet a common consensus about it (Gratton and Preuss, 2008). This concept if quite difficult to evaluate because it is based on the long-terms impacts of the Games on the city, and there is a lack of follow-up actions by the host city to assess the legacy of the Games. Gratton and Preuss (2008) argued that this lack of follow-up could be caused by political reasons, due to the fear of highlighting the negative impacts that the event had. Leopkey and Parent (2012) also pointed out the lack of definition and measurement techniques to conceptualise it. Nonetheless, through the study of the bid documents and reports from the different Games organisation, Leopkey and Parent (2012) tried to define the concept, through the division between tangible (e.g. infrastructures) and intangible (e.g. cultural, image, educational) legacies. The evolution of the concept, from a legacy based on sport infrastructures to changes in the urban context, and its increasing focus on social, economic and environment, and finally sustainability makes the concept of legacy a dynamic one (Leopkey and Parent, 2012).

In order to tackle those problems, Chen et al. (2013) created an analytical framework to try and capture the long-term impacts on host cities of mega events. This framework was then used for two case studies to qualitatively evaluate the long-term impacts of the Games. It was shown that Olympics can be used as an opportunity to initiate green efforts, and enhance environmental innovation in host city (Chen et al., 2013). Samuel and Stubbs (2013) shown that through a multi-case study of three Games editions, environmental awareness made during the preparation of the Games had positive impacts on some of the business which then started to change their practices to more environmental friendly ones. Here, one type of environmental legacy of the Games was highlighted. Yet, the relation between sustainability and legacy was questioned, especially whether those two concepts are overlapping or are in contradiction. The concept of legacy has grown within the Olympic Movement in parallel with the concept of sustainability. Through a case study on London 2012, Gold and Gold (2013) shown how the two concepts were used in practices. The failure of some sustainability practices, such as the lack of use of renewable energy or zero waste plan, has, according to the authors, highlighted that the focus was more put on the legacy part than on sustainability (Gold and Gold, 2013).

3.5   Sustainable Olympic Games?

Many recent studies regarding environmental sustainability and Olympic Games are more critical, questioning the possibility to stage sustainable Games under the current conditions set by the International Olympic Committee. This is the last of the five main topics identified on the relation between environmental sustainability and Olympic Games. This topic is the most recent ones that has been studied, and includes papers from different academic journals - environmental policy, sustainability or urban planning.

Geeraert and Gauthier (2018) presented reasons why, despite its engagement to integrate the environmental sustainability in the design of the Games, the International Olympic Committee fails to incentivise Olympic Committee for Olympic Games to comply with the objectives set towards sustainability. Based on a multi-case study design on multiple Games, from Beijing to Tokyo, their study highlights some of the failures and the underlying dynamics regarding environmental sustainability. Among others, the inefficiency of the latest reforms and lack of mandatory goals are some of the reasons of this failure. Another issue is the lack of follow-up after the Games in terms of impacts - mostly social, environmental and political impacts. Many discussions and controversies raising from activists and media regarding environmental issues occur prior to the staging of the Games. Yet, those issues are often forgotten after the Games as the focus and discussions are oriented towards the next Games, and some mistakes or failures that happened during one edition can be reiterated (Petersson and Vamling, 2016). Similarly, the fact that the IOC is largely a follower of initiatives led by the Olympic Committee rather than a leader in terms of environmental sustainability in the Olympic Movement is another issue impeding the staging of sustainable Games (Müller, 2015). A striking example for this problem is that the IOC only provides ideas on what initiatives could be implemented but there are not any mandatory requirements regarding environmental sustainability standard (Guthoff, 2016). It is also argued that Olympic Games are increasingly similar to each other, and do not consider anymore the specificity of each urban context. This is due to the consulting of the same groups of stakeholders for the creation and design of Olympic Games. Finally, the gap between the bid file and the reality is becoming larger. It is then more difficult for Organising Committee to fulfill the promises made in the bid, which are sometimes unworkable (Gaffney, 2013).

Many possible solutions are proposed by different authors to tackle all those issues. Those solutions include the use of a third party for the choice of the host city during the bid process in order to avoid corruption and increase transparency (Geeraert and Gauthier, 2018), the revision of the bid process in order to reduce the negative impacts (Gaffney, 2013), the setting of mandatory sustainability objectives (Müller, 2015), the introduction of sanctions for host locations that fail in achieving sustainability objectives (Geeraert and Gauthier, 2018), the monitoring of the impacts of the Games afterwards (Petersson and Vamling, 2016), and the introduction of an external third party to assess the measures towards environmental sustainability (Paquette et al., 2011)

Those are examples of possibles initiatives to be implemented by the IOC which aim at tackling the challenges presented before. Yet, it is not clear how those responses would help reduce the environmental impacts and enhance the sustainability of the Games. More information should be given on how concretely those measures should be implemented, and what would be their effects on the Games, and what would it mean for the other stakeholders to respect those new measures.

3.6   Sub-conclusion

The literature review shows that most of the existing literature qualitatively deals with the concept of sustainability and Olympic Games, through description or narrative reviews of different Games. The papers found come from a mix of many different disciplines which makes the subject studied under many different angles. Most of the reports take departure in specific editions of Olympic Games and analyse those Games, mostly through a content analysis of the report produce by the stakeholders of the Games. Other concepts are linked with sustainability: the legacy and urban development. Besides, an increasing number of paper focuses on the limit of the International Olympic Committee and the Olympic movement to really ensure that the concept of sustainability is fully embodied during the Olympic Games.

With the low number of research papers on the subject, it appears that the research on the relation of Olympic Games and environmental sustainability is at an early stage. Additionally, there is a lack of systemic evaluation of the environmental impacts of the Olympic Games, which makes it difficult to know whether the Games entails more negative or positive impacts. Also, if the relation of some sustainability dimensions and the Olympic Games has been widely analysed, some dimensions are still overlooked, such as the energy or the water sectors. Thus, more research should be performed on the understanding of the dynamics behind the failures and success of the sustainability responses by the Organising Committee and local governments. From those observations, by focusing on the understanding of the responses for water sustainability during the Games, this project really tries to fill a gap found in the existing literature regarding environmental sustainability and Olympic Games.

4 Analytical framework: the Driver-Pressure-State-Impact-Response model

This chapter presents the analytical framework used for this project, the Drivers-Pressure-State-Impact-Response (DPSIR) model. It first provides a presentation of the framework, then dives specifically into its application for urban water challenges and finally shows why this framework is especially relevant for the problem raised in this project.

4.1 Presentation of the DPSIR framework

4.1.1 Origin

The Drivers-Pressure-State-Impact-Response (DPSIR) framework is an evolution of the Stress Response framework (SR), developed at the end of the 1970s by Statistic Canada (Rapport, 1979). This first approach was then extended by different actors, including the Organization for Economic Co-operation and Development for environmental reporting at the beginning of the 1990's (OECD, 1991, 1993) and the United Nations (Nations, 2001). This resulted in the creation of the Pressure-State-Responses approach (PSR). An extension of the PSR framework, also developed in the late 1990's is the Drivers-Pressure-State-Impact-Response framework. This framework was created by the European Environmental Agency (EEA, 1999). This tool was developed for the analysis and reporting of environmental issues, from global to local scale (Carr et al., 2007). Since then, it has been widely used to as an approach to analyse the state of the environment, and further to organize and communicate complex environmental challenges. In fact, one of its main advantage is that it can link social science and environmental science, and the different scientific communities (Lewison et al., 2016), and can be used to construct new knowledge (Carr et al., 2007).

The main belief behind this approach deals with the fact that a part of a system is best understood when looking at the context of its relations and interactions with the other part of the system (Bradley and Yee, 2015). The objective of the DPSIR is thus to clarify relationships between cause and effects and highlight the dynamic characteristics between socioeconomic changes and ecosystems, but also to assess progress towards sustainability.

4.1.2 The Components of the framework

The framework consists in a chain of components that are linked with each other. The components of the framework are, according to Kristensen (2004):

- **Driving forces** represent the need of individuals or of the society. It often includes production and consumption needs and are divided into economic sectors (e.g. energy, transport).

- **Pressures** refer to the human activities which result from the driving forces. They are often divided into three main categories: the overuse of environmental resources, the emissions to air, water and soil and the changes in land use. Besides, pressures can relate to human behavior.

- **States** deal with the environmental conditions, which means that the quality of the different compartments of the environment (water, air and soil) are affected. Overall, it is a combination of the chemical, biological and physical state of the environment.

- **Impacts** refer to the different types of influences, related to the human health as well as the ecosystems, that the changes in states imply.

- **Responses** involve the efforts made to address a part of the chain, from driving forces to impacts.
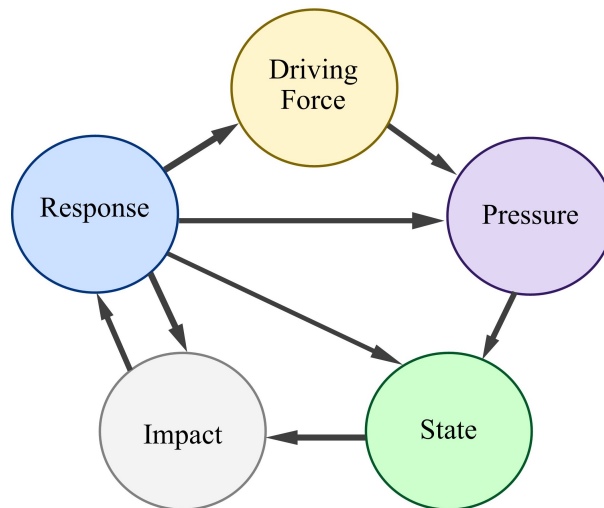
Figure 2: The DPSIR framework

Figure 2 presents the chain between the components of the framework. The main point that should be noted when looking at this figure is that the responses taken can affect any other components of the chain.

4.1.3 Indicators

Practically, to apply the framework, there is a need to define indicators for each component. It is then possible to monitor and quantify the relationships between the different components. For instance, monitoring the effect of a specific response on the other components could be an application of the framework.

Indicators for each components are quite different and are more or less responsive. Indicators for driving forces are not very responsive, as well as impact indicators. It means that when a measure is enforced as a response to reduce the driving forces or the impacts, it takes time for the indicators to respond. On the other hand, pressure and states indicators are more responsive, which means that it is possible to assess the reduction on the pressures of a specific response. Monitoring of success can thus be observed through pressure and state indicators (Fioravanti, 2008). Yet, responses to reduce the impacts and driving forces should not be overlooked, even though they are hard to quantitatively assess.

This framework has been used by many countries to create indicators to assess policy making, which has led to the listing of many different indicators, often classified depending on their themes (Kristensen, 2004). There is not a common agreement on which indicators should be used, or which ones are the best. Rather, the choice should rely on the theme and objective of the study, and the researcher should well justify his choice towards specific indicators.

4.1.4 Drawbacks of the framework

This framework has some drawbacks. First, there have been different interpretations of the framework, especially in the definition of each component. For instance, it is unclear whether the impact should include only the impacts on the human or consider the impact on the environment as well (Lewison et al., 2016). It has further been criticized for being too simplistic, which mean that this approach is not able to well represent the complexity of many systems. This can be related to the fact that a linear relationships is considered between the components, while the reality is much more complicated.

4.2 Application to urban water challenges

The DPSIR framework can be used for assessing water related issues. This method has in fact been widely applied to study water related challenges, either to look at water quality of water bodies (Lalande et al., 2014), to analyse the sustainability of coastal areas (Bidone and Lacerda, 2004) or to assess water resources (Sun et al., 2016; Venetsanou et al., 2015). This model is well adapted for water challenges, because the main objective when managing water sources is to maintain the sustainability of water ecosystems. It is thus essential to both identify and quantify the state and different impacts on water environment, and their evolution through time (Kristensen, 2004). Using this specific analytical framework for this project based on water sustainability is therefore relevant, as the model is well adapted for water challenges.
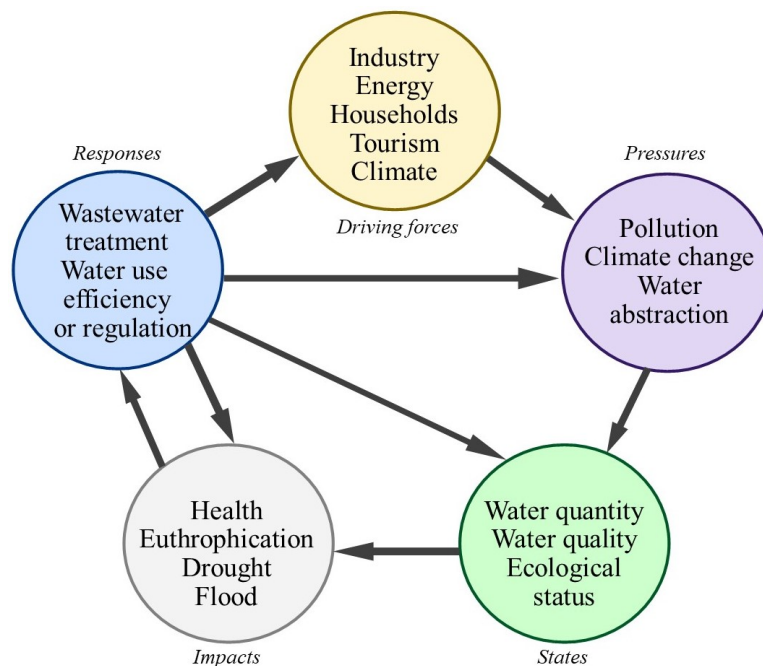
Figure 3: An example of DPSIR framework for water

The DPSIR framework applied to urban water is presented in Figure 3. It is based on different frameworks developed by other authors, Sun et al. (2016), who analysed the sustainability of the water system of a city in Mongolia, using the DPSIR framework. It also relies on Kristensen (2004) who made a comprehensive paper on the DPSIR framework and its specific application to water related issues. This figure does not aim to be a complete overview of the DPSIR chain for water challenges in urban areas. It only presents few examples of driving forces, pressures, states, impacts and responses.

4.3 Relevance of the DPSIR model for the project

This specific analytical framework was chosen for this project because first, it has never been used in the existing literature to analyse the dynamics between Olympic Games and the urban environment. Again, this framework is especially relevant for Olympic Games, because as previously mentioned, Olympic Games is both generator of negative environmental impacts and catalyst of change in the urban context. Additionally, during the Games, specific standards and requirements from the International Olympic Committee, as well as internal commitments must be met, in order to reduce the environmental load of Olympic Games. Yet, if those commitments and requirements are not reached, negative environmental impacts can arise. It is then interesting to evaluate and analyse the type the responses applied to fulfill such commitments and requirements.

Overall, this analytical framework is used to frame the structure of the analysis in order to understand how the Games are driving forces for negative environmental impacts. Likewise, this analytical framework helps to understand how the Games they can act as a response for urban water sustainability issues, by reducing the pressure of water resources and mitigating negative impacts.

5 Methodology

This chapter provides an overview of the method and systematic reasoning used in this project. Overall, this project aims at tackling the limits of the existing evaluation or assessment tools promoting environmental sustainability at Olympic Games, through the identification of possible initiatives to be implemented by the Olympic Games organisers or the International Olympic Committee. The first section presents the method used for the identification and analysis of the existing sustainability assessment tools for Olympic Games. The second section details and justifies the scope of the project. Finally, the third one displays the research design and method used to assess the current responses towards water sustainability and to provide possible initiatives to enhance the environmental sustainability of the Olympic Games and the host city.

5.1 Analysis of existing sustainability assessment framework for Olympic Games

The first analysis seeks to identify and discuss the existing sustainability assessment tools for Olympic Games. Two main types of tools were considered in this project: first, the tools that are used by the Games' organisers during the planning and preparation for the Olympic Games and second, the sustainability assessment tools for Olympic Games used or discussed in the academic literature.

Sustainability assessment tools used during the preparation for the Olympic Games

The first review was done within the documents produced by the Games' stakeholders such as the International Olympic Committee and the different Organising Committees, in order to have more information on each sustainability assessment tools, their types, their uses, the motivations behind the implementation of such tools. For instance, the sustainability strategy of the IOC presents some of the tools uses (IOC, 2017b). Additionally, more information on those tools were searched in the academic literature, in order to find whether they have already been discussed. Only one paper was found on one specific tool (Vanwynsberghe, 2015), otherwise no paper really focus on the discussion of those tools that are used during the preparation for the Olympic Games by the organisers.

Sustainability assessment tools in the existing literature

Secondly, in the academic literature, a search on papers dealing with the sustainability or environmental assessment of Olympic Games was conducted. This was not done in a systematic way, but was performed at the same time as the initial literature review performed on the relation between environmental sustainability and Olympic Games, because during this initial review, papers on sustainability assessment were found. Nonetheless, a specific literature search was achieved afterwards in order to identify missing papers that would have not been found in the initial literature review. This checking did not bring any additional papers.

Around 15 papers were identified assessing the environmental impacts or sustainability of events, but those papers include the assessment of different types of event, from small-scale to large scale and mega-events. To be more in line with the research on the Olympic Games and to reduce the number of papers, specific criteria of selection were used.

Only papers dealing specifically with Olympic Games were included, and those on smaller-scale events were put aside. In fact, the Olympic Games have much wider impacts than small-scale event which are more specialized, so it did not make sense to include those. As well, tools on mega-events but which do not deal with the Olympic Games but with other types of mega-event were not included either. Finally, six papers found during the review respected all the criteria.

Critical review

For each assessment tool identified, in order to highlight the limit of each tool a critical review was performed. This was needed in order to link the assessment tools with the theory behind sustainability assessment. This was further done in order to compare the real outcomes of the tools with the motivation behind their implementation and whether they fulfill the original goal.

5.2 Scope of the project

This section presents the scope of the project, and especially why Summer Olympic Games and water sustainability are studied.

5.2.1 Summer Olympic Games

For this project, only Summer Games are considered. This choice was done because it is considered that the Summer Games have much more impact on the urban environment, while Winter Games are more specialized and occur in a specific environmental (Pitts and Liao, 2013). Yet, some knowledge from this project could be transferable to Winter Games and other mega-sporting events, such as football cup, Asian Games or Panamerican Games. Other non-sporting events having an impact on the urban environment could likewise benefit from this project, such as world's fairs. Yet, the overall impact of those mega-events on the urban environment are probably less important than for the Games, so generalization should cautiously be carried out.

5.2.2 Focus on water sustainability

The sustainability plans of three Games were reviewed in order to identify the main dimensions tackled by the Olympic Games, related to environmental sustainability. For each plan, the main sustainability themes were retrieved. Table 1 presents the sustainability dimensions related to the organisation of the three Olympic Games studied.

Table 1: Sustainability dimensions mentioned in the sustainability reports of three Olympic Games

Beijing 2008	London 2012	Rio 2016
Air quality		
Water		
Transport		Transport & logistic
Energy	Climate change	Design & construction
Green coverage & protected area	Waste	Environmental conservation
Solid waste	Biodiversity	Waste management
Olympic sites & venues		
Climate neutrality		

From table 1, eight main recurrent environmental sustainability dimensions were identified. These dimensions are the subjects that are the most addressed by the organisers of the Games, as they are the ones approached in their sustainability objectives. Those eight sustainability dimensions include the energy, infrastructures & venues, waste, transport, resources, climate change, water and natural environment & biodiversity. Those are the main themes that planners must consider during the process of developing a bid and a plan for the Games. Each of those environmental sustainability themes are impacted positively or negatively by the staging of the Games, and has its own challenges which sometimes can be tackled by hosting the Games.

Not all the eight environmental sustainability themes identified were more deeply analysed in the project. This limitation was needed to narrow the research, because of the time limit of this project. This deep analysis was thus only performed for the challenges related to water, but the same methodology used to analyse water challenges can be applied for the other themes. The choice of the water issues among the eight sustainability themes was done based on the existing literature on the relation between those themes and Olympic Games. Chapter 3 on the existing literature shows a lack of study on the water related issues and Olympic Games, while other dimensions have been extensively studied. From a more practical perspective, the last Summer Games in Rio raised public discussions on the poor water quality at the sailing venues. Those two aspects guided the choice towards the analysis of the water dimension, in order to try and fill the gap in the existing literature, and provides practical initiatives to avoid any negative public discussion and risk of competition's cancellations during future Summer Olympic Games.

Some of the recommendations and initiatives provided based on the analysis of the water issues can be applied to the seven other sustainability dimensions identified above. Yet, generalization of the results for water sustainability should be carefully done, as more studies on the other sustainability dimensions should be performed in order to know whether the same recommendations could be provided.

5.3   Water sustainability and Olympic Games

This section presents an overview of the method used for the second analysis of this project: the relation between environmental sustainability and Olympic Games through the examination of a specific dimension, the water sustainability. A combination of qualitative and quantitative approach was adopted in order to answer the research questions related. This project essentially applied a qualitative research method with the review of reports on the three cases studies. The Games were further compared quantitatively, with the use of indicators to contrast the initiatives and responses of the different Games organisers.

5.3.1   Research design

The current existing frameworks used by Organising Committees might not ensure the staging of sustainable Olympic Games. Especially, the first analysis pointed out that there was lack of practical and concrete guidelines for Organising Committee. In order to create guidelines and to propose initiatives that would increase the environmental sustainability, a review of existing practices within the organisation must be fulfilled. This review must highlight the different positive dynamics and challenges towards the achievement of environmental sustainability.

A way to list and compare the initiatives related to water sustainability during the Olympic Games is to analyse different Games' editions. The research design used for this project is thus a multi-case study design, as more than one case-study are used and compared (Bryman, 2016). Yin (2017) argues that a benefit of doing case studies is the possibility of incorporating different sources. This is done by not only looking at official report but also other unofficial sources, such as reports from non governmental organisation or articles from newspapers. Case study are especially relevant to investigate contemporary phenomenon that happen within a real-life context (Yin, 2011).

In the analysis, three Games were studied: Beijing 2008, London 2012 and Rio 2016. It was considered to include Tokyo 2020, but as these Games have not yet happened, it would have been difficult to know what was successfully achieved or not. The most recent Games were investigated because they are likely to be the ones using state-of-the-art technologies, and introducing new strategies in terms of environmental sustainability. Different countries are represented by those three editions, developed country (United-Kingdom) and developing countries (China, Brazil). They also represent different continents (Asia, Europe, South America) and thus socio-cultural differences. Besides, studying those three editions is interesting in order to identify the evolution of practices of Games' organisers. The goal of the project is to analyse those three Games, but does not intend to find which Games were the most sustainable regarding water issues. Indeed, due to lack of quantitative evidence to assess the efficiency of each response, it was not possible to identify the most sustainable Games. Rather, the objective was to uncover the different responses towards water sustainability, and qualitatively discuss the efficiency of those responses.

Generalisation is an important issue when doing a case-study. Here, using three different cases might not be enough to have an accurate representation of the overall Olympic Games and thus one could argue it can be difficult to generalize the results (Blaikie and Priest, 2019). Yet, it is supposed that each Games' edition build on the previous one with as mention before, the Olympic Games knowledge transfer program, but that the practices and technologies are rapidly evolving and thus the sample here is considered sufficient to well represent the sustainability practices.

5.3.2 Method: Data collection

One of the main source used to collect data was the Olympic World Library. This library gathers public official reports from the Games, as well as research papers or any other articles related with the Olympic Games. Thus, the main source of data can be considered as social artifacts, as those reports trace social activities of people.

Presentation of the reports used
First, a literature review of the official reports of the three editions was carried out. Those reports were analysed to identify the commitments and responses associated. The next paragraphs present, for each editions, which official reports were reviewed.

For **Beijing 2008**, only two reports were used, the *Independent Environmental Assessment* (2009) written by the the United Nations Environment Program (UNEP) and another report called *China after the Olympics* (Greenpeace, 2008). Back in the 2000, it was not yet mandatory for Games' organisers to provide a comprehensive sustainability plan and write sustainability progress reports and a post-Games report. This explains why external stakeholders, in this case non-governmental organisations, which can be considered reliable, have made their own "impartial" report (UNEP, 2009, p2) to analyse the work made by the Games' organisers to fulfill the commitments from the bid file.

For **London 2012**, the sustainability plan called *Towards a one planet 2012: London 2012*, written by the London Organising Committee of Olympic Games (LOCOG) in relation with WWF provides the main sustainability themes that the Games cover, as well as the commitments related to those themes, and some of the actions considered to fulfill those commitments. A report written by the Olympic Delivery Authority (ODA), which was responsible for the construction of the Olympic Park, called *Delivering London 2012: environmental management* (Jackson and Bonard, 2011) was also handled. This report especially focuses on the measures taken in the Olympic Park. Finally, the final report of the Olympic Games Impact Study (UEL, 2013) written by the University of East London (UEL) provides information on the impacts of the measures taken for the Games.

For **Rio 2016**, three pre-Games reports were considered: the Sustainability Management Plan: Rio 2016 Olympic and Paralympic Games (2013), Embracing Change: Rio 2016 Sustainability report (2014) and the Post-Games Sustainability Report (2016a), all written by the Games' organiser, called Rio 2016. The first one presents the commitments and main actions taken to create sustainable Games, while the second one reports the progresses made towards the commitments. The Post-Games Sustainability Report (2016a) presents the sustainable outputs of the Games. Other sources were likewise considered for those Games, especially newspaper articles, and academic papers.

How the data were retrieved?
The content of each report was studied individually. First, a look at each part of the report related to water was reviewed. The rest of the report was then scrutinized by searching for the term "water" in the document. The elements inspected were first the commitments associated with water, then all the responses proposed to fulfill the commitments and finally all quantitative data related.

Coding was then used to group the findings between different categories. Those categories are the following ones: water quality, water availability and climate adaptation. Those three specific categories appear to be the three main areas tackled by the Games' organisers. Within each of those three focus points, another division was made between the commitments (including specific targets), the measures taken to fulfill the commitments, and the final results (i.e the efficiency of the responses). Those categories do not overlap to some extent, they cover all the possible measures taken related to water during Olympic Games.

- **Water availability** comprises the issue of water supply, which represents the amount of water that can be sustainably withdrawn from the different water sources (groundwater and surface water), and the water accessibility, which corresponds to the transport of sufficient water from the different sources to the places where water is used (e.g households, businesses, industries). The challenge of water supply occurs in city facing severe dry period, while water accessibility is mostly an issue in developing countries (UNESCO, 2019).

- **Water quality** is another issue which refers to the chemical and biological characteristic of water. This is especially important for the Games. Some of the competitions, like open water swimming, sailing or rowing, are held in rivers or coastal areas. The athletes are in direct contact with water, which must then fulfill bathing quality standard. This focus point only includes the water quality of open water - quality of drinking water will be addressed in the water availability. Water quality further refers to the treatment of wastewater, because the discharge of untreated sewage in open water is one of the main source of pollution.

- **Climate adaptation** includes two main related water challenges. Climate change entails a rising number and intensity of extreme events, including extreme rain or flood event.

Besides, the findings were classified depending on the scale of the responses. Two scales were considered, the city scale and the scale of Olympic infrastructures - for instance, Olympic Park or Olympic Villages. This division directly reflects the level of influence of the stakeholders pursuing the responses. Indeed, the Organising Committee for Olympic Games is responsible for the Games but work in collaboration with the local government. The local governments are responsible for the delivery of all the infrastructures that are not specific to the Games, such as the new transport infrastructures. The Delivery Authority and Organising Committee are responsible for the delivery of the infrastructure that are specific to the Games: the Olympic Park, Olympic Village, all the competition venues and other needed infrastructures, for instance the media village.

Validity and reliability of the results

A careful attention was given during the process of data collection because most of the sources used can be considered as skewed, as the main organisers of the Games are the authors of most of the sources used. The authors of those reports can represent the reality in a manner that is not detrimental for their work and their public image, but without saying the real truth. This is especially the case regarding the achievement or not of the initial commitments. The validity of the project can thus be questioned, as the conclusions made can be biased by the sources of the data. Various other sources, like newspaper articles, reports from Non-Governmental Organisations, and scholar publications were looked for in order to have a more objective and critical view on the reports from the Organising Committees.

The reliability, which represents how can personal bias influence the project, was likewise considered. The personal existing knowledge on the studied Olympic Games, and perception of the performance of each Games towards sustainability were put aside for the project, as much as possible. This was needed in order to make the project and results reproducible by other people.

5.3.3 Method: Data treatment

This part deals with how the data collected were treated and analysed. The first level of analysis seeks to map all the responses taken during the four Games studied. The second level of analysis aims at comparing those responses and investigates which ones have been efficient or not. The final level intends to provide recommendations for future Olympic Games.

In order to make sense of the data and frame the analysis, a specific analytical framework - the Drivers-Pressure-State-Impacts-Response (DPSIR) was applied to the water sustainability and Olympic Games.

Overall the analysis was specifically divided between the three categories identified above: water availability, water quality and water adaptation.

At the beginning of the project, it was considered to quantitatively assess and compare the different responses towards water sustainability. Yet, many difficulties were encountered to do this. First, it was noticed that there was a lack of communication by the different Games organisers on specific quantitative data related to water sustainability. Then, when common indicators and their scores were available, it was found that each Games have their own measurement method, which makes the comparison between the Games impossible. Besides, the relevance of indicators changes by country and context (OECD, 2003). It is then quite hard to compare quantitatively the three editions.

Therefore, most of the analysis was based on qualitative description and discussion of the responses, the underlying dynamics and their efficiency. Nonetheless, a quantitative approach was included for a minor part, in order for the project to be closer to the initial idea of quantitative assessment, and to show how the project could benefit from the use of this type of approach.

This quantitative approach was based on the use of indicators. Usually, the selection of indicators relies on on many different technical criteria, for instance, their validity, their interpretation or the availability of data (Ciegis et al., 2009). To be correctly interpreted and to explain the score, other qualitative and scientific information are provided. The most important criterion used for this project was the data availability, due to the lack of quantitative data identified during the research.

Water quality

For the water quality, two main indicators were identified. As the strategies and commitments of the cities are different for water quality, the indicators should be adaptable to each specific strategies.

To gauge the responses taken prior to the Games and analyse the state of the water quality during the Games, a qualitative indicator called "Water quality at Games Time" was defined as the quality of the water bodies that the Games organisers intend to improve during the preparation of the Games. A scale between one and five was used to gauge this quality: very poor (1) - poor - normal - good - very good (5). The score given was based on qualitative and personal interpretation. The indicator represents the commitment towards the quality improvement of water bodies.

The second indicator used for the water is the percentage of wastewater that is safely treated in the city during Games time. It is a quantitative indicator.

Water availability

One indicator was defined for the water availability which is the percentage of water savings in new permanent venues. This indicator represents well the different types of responses, including the use of water saving technologies and reclaimed water.

5.3.4 Initiatives

Finally, from the qualitative discussions of each responses and commitments, some initiatives were provided for the stakeholders of the Games, including the Organising Committee, the local government and the International Olympic Committee. Those initiatives were based on the personal interpretation of the success or failure of the responses towards water sustainability.

6 Assessment frameworks for sustainable Olympic Games

Different tools are used by the Games' organisers or other Olympics' stakeholders in order to enhance the sustainability of Olympic Games. This usage is part of the rising demand from organisations to evaluate and assess the impacts of their activities. The first section of this chapter elaborates on the need for such evaluation or assessment framework for sustainability. The next section presents four sustainability assessment tools that are effectively used by different stakeholders of the Olympics during the preparation of the Olympic Games. Finally, the third section displays other sustainability tools that were applied or academically discussed in the literature.

6.1 Theoretical perspective: Rising demand for sustainability evaluation

6.1.1 Sustainability assessment

Many organisations have started to integrate the concept of sustainability in their development strategies. Yet, this theoretical concept can be hard to capture, and further, to use in practice. One way to convert the concept of sustainability from a theoretical perspective to a decision-making approach is through the development of sustainability assessment (Ciegis et al., 2009). Sustainability assessment attempts to quantify the characteristics of a specific element. Quantification can be defined as the production of numbers, but also their communication, as it enables people and organisations to share the same language. In fact, many organizations demand for the quantification of intangible phenomena, like sustainability. The ultimate aim is to be able to work with those phenomena by making them visible (Espeland and Stevens, 2008). This trend goes in line with the growing adoption of assessment tools, which are used for the communication of results, but especially to justify projects. The overall goal is to increase transparency and accountability of authorities or other organisation (Waas et al., 2014).

Sustainability assessment has different objectives. From a theoretical perspective, it contributes to strengthen the understanding of the concept of sustainability and its interpretation (Ciegis et al., 2009). From a more practical perspective, the assessment of the sustainability impacts helps integrate sustainability issues into decision-making, in order to ensure that the final decision is taken based on the best knowledge of its full impact. Besides, the assessment can provide sometimes different choice opportunities, and finally foster sustainability objectives (Waas et al., 2014).

Sustainability assessment comprises many types of tools, that are used in different contexts, from the use by planners or policy makers to personal use. These are well implemented tools to assess sustainability at various scales, ranging from a national scale to a municipal scale, but also to buildings and products. The accessibility and construction of those assessment tools depend on the type of use and the object of assessment. Nonetheless, sustainable development is characterized by its numerous dimensions and its great number of interpretations which makes its assessment difficult and this creates a gap between discourse on sustainable development and implementation (Waas et al., 2014). At least, sustainability assessment should be used to structure the complexity of the concept.

6.1.2   Sustainability assessment for events

The sustainability and impact assessment of events experiences a growing interest among researchers. Yet, Getz and Page (2016) indicate that there is still a lack of uniformity in terms of environmental evaluation approaches in the event area. Moreover, Collins and Flynn (2008) point out that there is a need for quantitative assessment, as qualitative valuation cannot always guides decision makers to prioritize actions to limit negative impacts. Those missing elements might be due to the complexity of performing impact assessment of events. This complexity relies on the various thematic areas related to the staging of an event, that are interlinked, the geographical areas and the time-period related to the impacts (Theodoraki et al., 2016). Moreover, the larger the event is the more difficult it is to assess its sustainability, as this event can influence many different sustainability dimensions (Collins and Flynn, 2008).

In spite of those difficulties, different organisations tried to develop specific tools or used existing ones to either assess the environmental impacts of events or enhance the sustainability because, as mentioned in the last part, sustainability assessment has positive impacts on decision-makers.

6.2   Assessment tools used during the Olympic Games

As part of the growing trend of organisations to integrate the concept of sustainability in their strategies and despite the difficulty of dealing with large-scale events, the stakeholders of the Olympics have also started to use sustainability tools. This section presents the four sustainability evaluation tools currently used by those stakeholders during the preparation of the Games.

6.2.1   Olympic Games Impact Study

Presentation of framework and motivations behind

The International Olympic Committee developed a tool called "Olympic Games Impact Study", which aims at understanding and quantifying the potential impacts of Olympic Games on the host city, region and country. This tool was released in 2006 from a collaboration with universities and advisors to select and design the most appropriate assessment tools (IOC, 2006). This tool was the first one to be designed especially by the IOC to be used by Games' organisers. The main motive behind this creation was that the IOC was at that period trying to integrate the concept of sustainability in the Olympic movement (IOC, 2007). As mention in section 6.1.1, to be able to work with the concept of sustainability, the development of an assessment tools is a possible solution. This creation was thus motivated by a growing need to understand and structure the social, economic and environment impacts of staging Olympic Games, and thus to visualise invisible flows (UEL, 2013). This tool was built as part of the Knowledge Management Program, for Games Organisers to know more precisely the negative and positive impacts of former Olympic Games, to know the areas they should focus on and thus to stimulate the decision-making process of Games' organisers (Vanwynsberghe, 2015). Finally, the creation of this tool was also a way to facilitate the comparison between Olympic Games, in terms of sustainability (IOC, 2006).

Application and advantages

This tool is an indicator-based assessment for cross-sector project specifically designed for the Games, in order to make the concept of sustainability quantitative and operational. It is a mandatory tool, which means that Games' organisers must apply it. The presentation of the indicators and use of this tool is available in the technical manual developed by the International Olympic Committee, available here.

The Olympic Games Impact Study includes 120 indicators which represent each a specific economic (44 indicators), environmental (34 indicators) or social (48 indicators) aspects that can be impacted for the Games, and well represents the concept of sustainability. It is performed over a period of 11 years, including nine years before the Games and three after (IOC, 2007). During this period, each indicator is measured four times, including three times before the staging of the Games and one time after. It is then possible to observe the evolution of each indicators over a long period, and then see whether the Games had a positive, negative or none impact on the studied aspects (UEL, 2013). This study is to be performed by another organisation than the Organising Committee, even though it is the OCOG which has the overall responsibility of delivering the different reports. This organisation is usually a local university, because it is a time-consuming task to conduct such study, but also because the Organising Committee does not necessarily have the skills to perform it.

The main audiences are first the future candidate and host cities which have the opportunity to shape their strategies and enhance the long-terms benefits through the understanding of the impacts of past strategic directions taken by former Olympic Games. The second audiences are the stakeholders of the Olympic movement, as the application of this tool seeks to enhance the understanding of the impacts of the Olympic Games.

The Olympic Games Impact study was first performed for the Winter Games in Vancouver in 2010, and is now mandatory to complete for each Olympiad. This tool was entirely performed for the Summer Games in London in 2012 and for the Winter Games in Sochi, while the study is still pending for Rio 2016, as the last report of the study has not yet been released. One of the main advantage of this tool is that it was specifically built for the Olympic Games, so it is very well adapted for this specific context. Likewise, it groups indicators from the three sustainability pillars, which makes the tool quite comprehensive.

Limitations

Despite its recentness, this tool is already questioned. The main criticisms rely on its lack of sustainability standard to compare the results to and its timeframe incompleteness (Vanwynsberghe, 2015). This timeframe issue is probably one of the main problem. Indeed, this framework intends to quantitatively measure whether hosting the Games represents a positive change towards sustainability, but the last measurement for the indicators is performed two years after the end of the Games, and it is often argued that only looking two years after the Games do not enable to capture the long-term impacts (Gratton and Preuss, 2008). Besides, the lack of sustainability standard creates uncertainty on whether sustainability is achieved. Indeed, "sustainability indicators should be linked to some reference values and targets" (Moldan et al., 2012, p.12).

One of the main challenges when using the OGI study is to know whether the evolution observed for a specific indicators can be attributed to the staging of the Games, or is due to any other external factor (Vanwynsberghe, 2015). For instance, changes for an indicator could be attributed to the implementation of an environmental measures not-related to the staging of the Games, and the changes observed would be due to this implementation. Additionally, it is not mandatory to use all the indicators; some are mandatory and other optional. Yet, when the study is made, the choice of which indicators to include is mainly based on the availability and accessibility of data (UEL, 2013), and not on the relevance of those indicators. This issue questions the validity and reliability of using such tool.

This tool is an evaluation tool rather than a decision-making one, and so far, none of the Games' organisers have used the results of the OGI studies from former Olympic Games to see which sustainability issues should be taken more carefully than others. On the one hand, this could be due to the considerable number of indicators that should be reviewed, more than 100. It is indeed argued that to serve communication in order to guide towards decision-making for sustainable development, a limited number of indicators should be used (Spangenberg, 2002). On the other hand, it can be argued that the timeframe does not provide enough time to study those reports. The final report of one Games, which really concludes on which aspects were impacted, is released three years after the end of those Games so one year before the next Games. Thus, it makes it very difficult for the future Games organisers to use the outputs of the study. Also, the external stakeholders fulfilling the study mostly use data given by the main Organizing Committee, while in order to be fully objective and transparent, this study should be independently performed.

Overall, the positive impacts on the environmental sustainability of this indicator based assessment tool specifically designed for the Olympic Games appear to be limited, mainly because of methodological limitations. The complexity of the Olympic Games makes the assessment of their impacts difficult. All those issues reduce the effects of the use of this tool on the decision-making. Nonetheless, it provides a new and quantitative understanding on the possible impacts of the Olympic Games, and in this way, increases the understanding of the concept of sustainability within the Olympic Games.

6.2.2 Certification: ISO 20121

Another type of tool for sustainability are the certifications or standards. It was made mandatory by the International Olympic Committee that each Organising Committee for Olympic Games get a specific certification, called ISO 20121 (IOC, 2017b). It is a third party certification created by the event industry to be used by event organisers. The use of this certification aims at raising the credibility of the Olympic movements towards sustainability, and to further orientate the practices of the Olympics' stakeholders towards more sustainable ones. Legitimisation, and the need to be recognized by other stakeholders are further reasons for the mandatory use of the tool. This is in fact necessary to, in a way, "prove" to the public, governments and all stakeholders that are against the staging of the Games that those Games are prepared and staged in a sustainable way.

This standard was first introduced after the London Games in 2012, and establishes the requirements for a sustainability management system. A management system is a combination of policies, procedures and processes used by an organisation in order to ensure that the tasks required can be fulfilled to achieve the objective (Bakos, 2019). Besides, this norm provides guidance to support the implementation of a sustainable event for the organisers. It is not a decision-making tool, but provides a framework guiding organisers to identify the potential negative impacts of the Games. This ISO standard is relevant for mega-event as well as small conference, and many other types of events were certified with the ISO 20121. The organizing committee in London was the first one to use such kind of framework, and the IOC, in order to further increase transparency and accountability of the Organising Committee decided to make this standard mandatory (IOC, 2017b).

This standard is based on the plan-do-check-act process (ISO, 2012).

- The **planning** phase deals with the decision of the scope, the definition of sustainable development and the identification of main issues and objectives that must be fulfilled. The Organising Committee for the Olympic Games creates a high level sustainability plan (between three and four years before the Games) including the different issues and principles that should guide the sustainable preparation and organisation of the G Games. Functional areas or thematic areas are included in the program, those themes are chosen by using reports from well-known international organisations (IPCC, United Nations with the SDG, Conference of Parties, Olympic Charter etc.) which highlight current challenges. The sustainability management plan is also based on the bid commitments, the inputs received from sustainability experts, other key actors and important partners.

- The **doing** phase deals with the implementation of policies to fulfill the objectives previously defined through the provision of resources and communication between different stakeholders. The actions defined in the plan are implemented by the different Games' organisers.

- The **checking** phase deals with the verification of whether the targets or measures are fulfilled through the monitoring and evaluation of actions. For this phase, the Organising Committee releases progress reports consisting in qualitative discussion of what have been done, the actions that have positively performed or not, and what still needs to be done to fulfill the objective.

- The **acting** phase relies on the identification of non-compliance and the application of corrective actions. In the progress reports, non-compliance are identified and specific actions are presented to tackle this issue, and then implemented.

A final report is released after the Games to present the results, including whether the objectives were achieved or not. Overall, the use of this tool really helps to integrate the concept of sustainability within the Olympic Games. In 2008, Beijing did not have to be certified and only made a list of 20 commitments, without any justification or detailed responses (UNEP, 2009). With the mandatory sustainability plan for each Games, the organisers really need to include sustainability in their plan for the Games in a structured manner. This was the case for London in 2012 and Rio in 2016, where the concept of sustainability was fully integrated in their management and practices. This tool also increases transparency of the Organising Committee towards their sustainability practices, and provides the public more possibility to follow the strategy of the Games' organisers.

If this standard plays a role in the integration of the concept of sustainability in the Olympic movement, in practice, it does not ensure that the Games are sustainable. This tool does not measure nor consider the sustainability consequences of an event. It is the organisation which is compliant with the standard and not the event itself. The processes are regulated, but the outcomes (or effectiveness) of those processes are not evaluated.

Moreover, it does not specify which sustainability issues should be managed and what performance should be achieved. It means that each Organising Committee designs its own framework depending on its own interpretation of the concept of sustainability. Objectives and key performance indicators chosen are thus different among the Olympic Games.

This non-specific particularity makes this ISO norm adaptable to many different types of event, and to different context, so it means that it is a very flexible tool that can be easily applied in many cases. It is then the responsibility of the organisers to select the main sustainability issues and to find appropriate solutions to reduce the impacts. On the one hand, this is a positive characteristic, as Games occur in different urban context. On the other hand, it does not provide any guidance for the Games' organisers about the main issues to be dealt with and the type of initiatives to introduce in order to tackle those issues.

By looking at the different sustainability plans and reports from different Games, other limitations related to the use of this ISO standard appear. First, for some key performance indicators, there is a lack of target which makes the achievement of the objective related to the indicators difficult (Rio 2016, 2013). As mentioned before, for the Olympic Games Impact Study, sustainability indicators should be linked to targets or objectives in order to be effective (Moldan et al., 2012). Some indicators, which are all defined before the Games, are not (or are said to be not) measurable in the post-Games report and this prevent the acknowledgement of whether the measures taken to fulfill the objective were effective. One can wonder whether this is deliberately done by the Organising Committee, in order too hide some negative scores, or if it is the reality. For instance, Rio 2016 had a target regarding the reduction of water consumption which was measured with a specific indicator: "% of new bathrooms procured by Rio 2016 with water efficient fixtures" (Rio 2016, 2016a, p.36). In the final report, no score is given to this specific indicator due to an impossible quantification.

Overall, even though some objectives are not achieved, there is no explanation of why and what could have been done differently. In fact, organisations are not obliged to provide evidence of positive results from the implementation of the ISO standard so it is difficult to know whether the sustainability plan was successful or not. Then, numbers provided in the study are internally measured, which mean that it is the Organising Committee which evaluates each indicator, and third party is not required to maintain neutrality and fairness for those numbers. Another important issue is the lack of post-Games objective. This is due to the fact that the Organising Committee dissolves two years after the game, and their main commitments is towards the good staging of the Games and not the management of the legacy after the Games. Finally, organisers are not sanctioned if targets are not achieved, so the effectiveness of the tool can be questionable because it is not mandatory to fulfill the objectives.

If this tool shows a great success over the integration of the concept of sustainability within the practices of the Olympics' stakeholders, some improvements are needed to make this ISO standard a catalyst for sustainable Olympic Games. The implementation of new guidelines for Games' organisers to be used during the making of the sustainability plan is one of the direction to take in order to increase the efficiency of this tool.

6.2.3 Green Building Certification

Another type of certification used during the Olympic Games is the green building certification. Those certifications are tools used to decrease the impacts of buildings on the environment through the use of state-of-the-art technologies and sustainable design. Many different types of green certification have been developed around the world, and a growing number of buildings, new or existing, or neighbourhoods are getting this type of certification (Qiu et al., 2015). As part of this global trend, there is a rising adoption by the Organising Committees and Olympic Delivery Authorities to try certifying the new permanent venues that they specifically build for the Games. It is not mandatory that the new venues must get certifications, yet the Committees really try to get them for their new buildings.

Those certifications provide a framework guiding the fulfillment of sustainability commitments. The certification company provides consultancy to the Delivery Authority and Organising Committee for the sustainable design of their new buildings. Like for the ISO standard, those tools aspire to increase the legitimisation of the Games' organisers, because it shows that the new buildings are built under the highest sustainability standards, so with low impacts. The use of this type of tool also shows that a specific procedure and guidelines were applied during the planning and building of the new infrastructures.

For instance, in London, the BREEAM (Building Research Establishment Environmental Assessment Methodology) certification was used for some of the new permanent venues: the Olympic Stadium, the Aquatic Center, the Velodrome (LOCOG, 2011). In Rio, the Olympic Village was the first neighbourhood in Brazil to receive the LEED certification (Leadership in Energy and Environmental Design). Overall, those tools aims at decreasing the environmental impacts of the infrastructures built for the Games, because they ensure the use of higher sustainability standards (for energy, water consumption, accessiblity etc.) than when no certification is used. One can nonetheless wonder whether those really ensure that the buildings or neighbourhoods are really sustainable. The fact that there is a strict deadline for the delivery of the infrastructures often leads to the need to shorten some procedures, and to leave behind requirements. For the Olympic Village in Rio, it was found that it was not built with conscientiousness. Among others, electrical problems, water flowing on the walls due leaking pipes and blocked toilets prevented some athletes to get access to the Village at the beginning of the Games (Baum and Cherny, 2016).

Plus, the certification does not impede social or economic challenges. In Rio, households were evicted from the area where the Olympic Village and surrounding roads were been built. The Olympic Village was as well supposed to become a wealthy neighbourhood with expensive apartments, but the project does not include any social mix housing, which is an important part of the social part of the LEED certification (Ana, 2015). A lack of public consultation, including all types of communities in the area, and not only stakeholders of the Games was also experienced during the project (Ana, 2015). Additionally, building certification does not ensure the use of the building after the Games. Even though a new building get a certification, this building can be underused after the Games, and this questions the impacts of the whole life-cycle of the building. For instance, the Olympic Village in Rio was supposed to be transformed into a luxury neighbourhood. Yet, after the Games, only 7% of the apartments have been sold, and still a great number of apartments are empty nowadays (Bauer, 2017).

One can wonder why not all the new infrastructures built for the Games are not externally certified. It is not made clear by the Games' organisers why some buildings are certified and others not. The short delay to achieve the work for the Games and imperative deadline could be one reason. This makes the aspect of sustainability less crucial. Another reason might be that the Games' organisers perfectly know that they are not building a sustainable infrastructure so they would not engage in any sustainability assessment for those infrastructures. Yet, those reasons are only presumptions and more research would be needed on the understanding of the use of green building certification and underlying motivations within the Olympic movement.

It is mostly new buildings that get environmental certifications, but no existing venues used for the Games have never been certified. Besides, green certification of temporary buildings is still not extremely developed, and no temporary venues used for the Games has never been certified. Yet, in the future Games, there will be a growing use of temporary and existing infrastructures. Thus, Games' organisers should consider getting certification for those buildings.

6.2.4 Carbon footprint

A carbon footprint aims at measuring the total greenhouse gas emissions caused by a product, an individual or an event. The carbon footprint measurement is a widely used tool among organisations to reduce their impacts on climate change. The International Olympic Committee released in 2019 a common methodology to measure the carbon footprint of the Games (IOC, 2018). Previously, London (2012) and Rio (2016) both performed a carbon footprint study for their Games, using each their own method (LOCOG, 2010; Rio 2016, 2016b). This common methodology released by the IOC, available here is essential in order to have the same framework between the Games and thus to be able to compare the Games. Making a carbon footprint for the Games is an extensive work as a huge amount of data is needed. This was implemented in order to provide a clear statement of the existing challenges of the preparation and staging of the Games. The main benefit of using this tool is the possible identification of the areas having the biggest impacts of the environment regarding climate change (e.g. emission of carbon dioxide). This helps the identification of area where more sustainable solutions must be found.

Even though this tool is still at an early stage of application, it seems to be quite a useful tool for Games organisers to reduce the impacts on climate change. The Organising Committee performs a carbon footprint prior to the Games, and this enabled the identification of the main areas responsible for climate change. Rio and London both used the tool to take proactive measures in those areas to reduce their impacts (LOCOG, 2010; Rio 2016, 2016b). For London, the total carbon footprint was estimated at 3.4Mt CO_2e . This study also shown that the transport of spectator to the Games and the building of venues and infrastructures have the highest impacts on climate change (LOCOG, 2010). Measures to reduce the footprint included the reduction of energy use at venues, for instance through the lowering of the floor space. The Games finally succeeded in decreasing their carbon dioxide emissions by 28% (Chestney, 2012). Yet, this tool only deals with climate change and carbon dioxide emissions, and climate change is only one type of impacts on the environment. This tool should thus be complemented with additional tools tackling the other environmental issues, in order to have an overall view of the environmental impacts of Olympic Games. Additionally, it is a complex tool for the Olympic Games because the scope of the Games is extremely large. Then, the scope of emissions is quite difficult to define, as it should be known which emissions can be totally attributed to the Games and which are not entirely linked to it.

6.2.5 Sub-Conclusion

Four main tools have been integrated in the preparation of the Olympic Games. Table 2 presents an overview of the main information on those tools. Those are complementary, as they all have different objectives and tackled different issues (climate change, infrastructure, management system). Yet, none of those are completely satisfying, all have some limitations. For some tools, there is still lack of evidence that the use of those really participate in the improvement of the sustainability of the Games. Additionally, none of them provides specific guidelines to be used by the Games' organisers during decision-making.

Table 2: A review of the sustainability assessment frameworks used during the preparation of the Games by the Games' organisers

Tool	Olympic Games Impact	ISO 20121	Green building certification	Carbon footprint
Types	Indicator based Cross-sector project Mandatory for OCOG	Third-party certification Cross-sector policy Mandatory for OCOG	Third-party certification Cross-sector project Voluntary for OCOG	Model Sector-specific project Voluntary for OCOG
Object of assessment	Olympic Games	Management system of the Games organisers	New infrastructures built for the Games	Olympic Games
Aims	Quantitatively measure the impacts of the Games to increase the knowledge	Introduce a sustainable management system within the Olympic Games organisation Structure the sustainability objectives	Build new infrastructures based on the highest sustainability standards, with state-of-the-art technologies	Identify the areas having the highest climate impact Reduce the climate footprint of the Games
Motivation	Make sustainability quantitative & operational Visualise invisible flows	Defining standards Find common language, Increase legitimacy	Show the best choice between different technologies Increase legitimacy	Calculate the environmental consequences of various decisions
Used by	London 2012 Rio 2016	Rio 2016 Tokyo 2020	Beijing 2008 London 2012 Rio 2016	London 2012 Rio 2016
Main receiver	Future OCOG All Games' stakeholders	Public	Public Local Governments	Public OCOG

6.3   Tools developed in the academic literature

This section presents sustainability assessment tools for Olympic Games that are introduced, used or discussed in the existing literature on sustainability assessment and Olympic Games.

6.3.1   Indicator-based sustainability assessment

Pitts and Liao (2013) developed an assessment technique in order to evaluate and promote sustainable urban development and Olympic design. This tool was developed as an evaluation framework, based on outcomes of previous events, using detailed analysis of the Olympic Games since 1896. It seeks to be used by the Organising committee at an early stage, to reflect on the decision associated with the development of the Games - mostly the planning and design. The tool is divided into nine different assessment issues - including for instance the transportation, the energy consumption, master plan and site selection or the water conservation - which represent the main issues regarding development of large-scale event. Assessment criteria are defined for each themes, and are only based on qualitative score - good, medium or poor. This tool can be used for meaningful comparison between the performance of different Games (Pitts and Liao, 2013). Yet, the evaluation is based on the assessor's understanding of the design and plan of the Games. Also, as the context of each Games is different, the tool needs to be adapted for each edition, and the comparative goal of the tool is then weaken. Additionally, only a presentation of the tool is provided in their paper, but it is not very clear how to use it concretely for the Games, what it can bring for the Games' stakeholders and what was the motivation behind the creation of this specific tool. Nonetheless, as the authors mention, it is more the outcome of the research that is valuable, while the tool provided should be refined in order to be effective (Pitts and Liao, 2013).

6.3.2   Ecological Footprint

The ecological footprint is a widely known tool, based on the a quantitative assessment of the resource use, in comparison with the overall availability of this resource. It was used by Collins and Flynn (2008) to assess the environmental sustainability of the Final Cup of the UK's Football Association, which is a small-scale event. The application of this tool for a case study seeks to show how this tool could be used for larger event, such as Olympic Games. The results show that the visitor travel, so the transport part, has the most significant impact on the footprint, followed by the consumption of food and drink. As only one stadium is used for this final cup and was already built, the impact of the infrastructure is very low.

It is then concluded that the application of this tool shows that it is a good way to communicate the scale of the impacts associated with the events, and to suggest potential areas of intervention to policy-makers, where different scenarios could be modeled (Collins and Flynn, 2008). It is finally argued that this tool could be used for Olympic Games, but the size of these events, the number of infrastructure used and the indirect impacts of the Games would make the use of this tool very difficult. In fact, no study was found during the project on the measurement of the ecological footprint of an Olympic Games.

6.3.3 Life cycle assessment

Life cycle assessment (LCA) is also applied to assess the environmental impacts of events. This tool is a method used to assess the environmental impacts of all the life-cycle stages of a product. This methodology is only approached in the literature, and it has never been used by any Organising Committee.

The LCA was first used to assess the direct and indirect emissions from different post-event waste management scenarios, in a study called *"Life cycle assessment of integrated waste management systems for alternative legacy scenarios of the London Olympic Park"* (Parkes et al., 2015). The overall objective of this study is to evaluate and then compare emissions resulting from different waste management scenarios for the London Olympic Park (Parkes et al., 2015). The main outputs of the study are that the savings occur through materials recycling at a material recycling facility, as well as through energy recovery, which then should be promoted over other waste disposal options. Another life cycle assessment was conducted to assess the overall greenhouse gas emissions of the whole life-cycle of an urban project: from the construction, staging of the event to the post-site redevelopment. It was applied to the London Olympic Park and three design scenarios for the post-event site were compared (Parkes et al., 2016). This assessment first shows that it is the legacy phase which has the highest environmental impacts, with the transportation of residents within the Park. This shows that the main focus during the planning of the Games should be on the legacy-phase rather than on the usage during the Olympic Games.

Those applications show how life cycle assessment can be used as a valuable tool to compare different planning strategies from an environmental perspective, and guide stakeholders to take specific decision during the planning phase. Yet, this tool is not accessible to everyone, must be performed by LCA practitioners, and requires a large amount of data. Those applications are based on one specific sustainability dimension: the waste management or the infrastructures. No study has been made on the overall life cycle assessment of an Olympic Games, probably due to the complexity of such event. Yet, for less complex event, Dolf (2017) and Toniolo et al. (2017) performed LCA for small scale event, considering the preparation, use and dismantling phase in order to highlight areas where the negative environmental impacts are significant. The main contributors to negative environmental impacts really depend on the type of event, and no common conclusion can be drawn from those two studies.

6.3.4 Scoring tools

Besides, the literature includes sustainability scoring tools for Olympic Games.

Rowberg and Rincker (2019) tried to evaluate the environmental sustainability of Olympic Games. The main goal of their tool is to provide feedbacks to the Organising Committee on its environmental measures at an early stage, and to some extent refine its sustainability plan.

A sustainability evaluation matrix was created based on the environmental sustainability dimensions from the Rio's bid report, and then a comparison was made between Rio 2016 and Tokyo 2020. Within each dimensions, activities or events which have an impact on the dimension are listed and are given a positive or negative weight. This weight chosen for each activity depends on the effect of this activity, a high positive weight would mean that the activity has a significant positive environmental impact, and a low negative weight a strong negative impact. For the dimensions "Water treatment and Conservation" a score of -1 is attributed to Rio and a score of 1 for Tokyo. Finally, each game that is evaluated is given a final score, a weighted sum of the score for each dimension, eight for Rio and 14 for Tokyo (Rowberg and Rincker, 2019). This tool is interesting because it provides an overview of the environmental measures, and is dynamic, as the final score changes each time a measure is added. The main problem with this tool is the lack of transparency on how each score was given for each environmental measures, if it is based on the authors' judgement or on specific data. Another issue is the lack of explanation on how this tool can effectively provide feedback on environmental measures, and who should use this tool.

Boroghi et al. (2018) developed an indicator based scoring tools in order to know whether the hosting of the 2016 Games in Rio was consistent with the sustainability goals of the city. The indicators used were selected from the existing literature about the impacts of mega-event, and were divided into four main categories: physical, economic, environmental, and social. Then, sustainability sub-themes were selected, in order to see the degree of sustainability of the impacts of the Games on the host city. To represent this degree, for each indicator, a score between -2 (extremely low) to 2 (extremely high) was attributed, but no explanation was given on why a specific score was attributed to an indicator. It was found a majority of negative scores, which show that hosting event mostly have negative impacts on the sustainability of host city. This tool is a post-Games evaluation of the sustainability objectives. It does not aim at guiding the organisers creating sustainable Games. The lack of transparency regarding the creation of the tool and the scoring approach does not make it really useful for other Games.

The tools that were developed in the literature especially for Olympic Games (Pitts and Liao, 2013; Rowberg and Rincker, 2019; Boroghi et al., 2018) have some limitations. Those limitations mainly rely on methodological aspects. The use of the Ecological Footprint and Life Cycle Assessment for the Olympic Games has also been discussed, and the main results are that it can provide valuable insights for decision-making, especially the LCA, but that those tools are really complex to be used for the overall scope of the Games. Rather, they should be used for specific sustainability dimensions.

6.4 The complexity of sustainability assessment for Olympic Games

The sections above presented some of the frameworks use to either evaluate, assess or promote the environmental sustainability of Games. It does not intend to cover all the existing tools, rather it gives an overview of the existing literature on those. Additionally, many other tools exist for assessing the environmental impacts of events, which are often easy to use, but too simplistic for Olympic Games, because the Games imply much wider impacts (Boggia et al., 2018).

Overall, the environmental evaluation of Olympic Games experiences different approaches and strategies. For the moment, there is not a common method that prevails over the others and each approach has its advantages and drawbacks. Those drawbacks mainly include the lack of transparency, the complexity or the inaccuracy of the framework. The Games-specific tools developed in the literature are mostly based on qualitative evaluation, because of the lack of available quantitative data. If more quantitative data were available, maybe new tools could be created or some could be improved to fit the Games.

In terms of results and topics, the infrastructure, transport, waste sectors and climate change are some of the most studied dimensions within the existing tools, probably because they have greater impacts. Some other topics are overlooked, especially for instance the energy, the water or the biodiversity, even though for instance water and energy are included in the building sector.

There are still uncertainty about the outcomes of some of the tools, such as the Olympic Games Impact Study, and especially whether the results are used as they are supposed to be. Usually, tools are elaborated to be used in specific contexts. The Olympic Games give a common structure and context, but each Games have its own design and plan, so it makes the use of specific tools difficult. Thus, none of the tools presented above is completely satisfying. The fact that many authors tried to contribute to the existing literature on assessing sustainability of mega-events shows that there is not a common consensus on which type of tools should be preferred over others. The right combination of several sustainability tools could be a solution.

All those observations show that to stage sustainable Games, the need might be for a combination of tools and other types of tool that would really make the difference for Organising Committee. In fact, there is not a common framework including the most important and common positive and negative impacts of the Games, neither the best initiatives and feasible solutions to reduce or enhance those impacts. The understanding of the dynamics behind each success or failure of sustainability initiatives would be needed for instance for the ISO standard, in order to guide the Organising Committee towards more achievable sustainability objective, tailored to the local context.

7 Environmental sustainability and Olympic Games: the example of water

This chapter highlights the main findings of the multi-case study performed during this project. The first section presents the case-studies analysed. A review of the responses towards water sustainability is then provided, using the DPSIR framework to structure it. Finally, initiatives for Games' stakeholders to enhance the water sustainability of the host city are provided.

7.1 Presentation of the case studies

This first section sets the context of this second analysis, with a presentation of three case-studies used in this project, in order to fully understand the context and the design of each Games.

7.1.1 Beijing 2008

Beijing was awarded the Olympic Games in 2001, after the failure of the bid for the 2000 Games back in 1993. This has been considered as a significant success by the Chinese government, which wanted, through the hosting of the Olympic Games, to open up Beijing and China to the world (Zhou et al., 2012). The failure of the first bid has motivated the government to improve the qualifications needed for the Games, in terms of infrastructures and public support. Billions of dollars were invested into public infrastructures every year, and prior to the second bid, Beijing was equipped with a very large number of sport facilities and new transport infrastructures. The winning of the bid would even more strengthen the public investment in new infrastructures, and would speed up the existing environmental protection plans (Beijing 2008, 2009).

The Beijing Games were held in August 2008. It was the third time that the Games were hosted in an Asian country. The main concept behind the Games was "Green Olympics, High-Tech Olympic and People's Olympics" (Beijing 2008, 2009). The design of the Games mainly relies on the extension of the northern axis of the city, with sport venues and other necessary infrastructures built along this axis. In the northern part, a forest park was created for the Games and remains as one major green legacy. Those constructions were possible because of the availability of lands which was reserved to the 1990 Asian Games. This part of the city was developed especially for the Games, but other investments were made for other parts of the city. The government decided to invest in public infrastructures and in environmental challenges, in order to improve the liveability of the city (Zhou et al., 2012). For instance, in terms of transport infrastructures, the capacity of the Beijing Capital airport was increased, new subway lines were built, as well as ring roads around the city and an airport express road. In terms of environmental issues, the main challenge was to improve air quality during the Games in order to avoid any health issue for the athletes and spectators. Many aggressive measures were taken to reduce air pollution, such as the upgrading of coal-burning boilers, restriction of the use on private automobile use and the shutdown of polluting industries in the surrounding of Beijing during Games' time (UNEP, 2009).

Regarding water issues, Beijing was facing different challenges. First, the limited local water resources combined with the population growth, as well as a reduction of water quality due to pollution used to lead to severe water shortages (Probe International, 2008). There were issues regarding the water quality of the water bodies and the seas, due to the uncontrolled flowing of untreated sewage. Besides, a lack of water resource management was observed back in the 1990's. Better urban water management was needed to cope with the numerous water challenges in the years preceding the Olympic Games (UNEP, 2009).

7.1.2 London 2012

Back in 2005, London won the bid for the 2012 Olympic Games. It was the third time in history that London was awarded the Games, after the Games in 1908 and 1948. The willing of the local government when making the bid for 2012 was to regenerate a neglected part of the city, the Lower Lea Valley, and develop this part as the Olympic Park (LOCOG, 2005). The site chosen was a former industrial site, a brownfield area, which was heavily polluted with petrol, oil and heavy metals surrounded by poorly maintained waterways. Those Games act as catalyst and fast-track process for urban redevelopment but also social and economic change. This project was the biggest construction project that United Kingdom has seen for decades (LOCOG, 2012). Apart from the regeneration of this neighbourhood, there has been an extensive use of existing infrastructures, with 61% of the infrastructures needed for the Games being already built in the city (Schmedes, 2015).

One of the main characteristics of those Games was the emphasis put on legacy. The Olympic Park was transformed to become a new park, including housing, schools, business spaces etc. The Olympic Village was transformed into flats and residences, including affordable housing. Another aspect of the legacy is the transport refurbishment, with new bridges and new railway lines built in order to connect the different Olympic Sites with the surrounding neighbourhoods. An important emphasis was again put on the upgrading of cycling and pedestrian routes throughout the city (LOCOG, 2005).

In terms of sustainability, the Organising Committee really tried to develop new and innovative strategies and plan to improve the environmental conditions of the Games. The first ever sustainability plan for Olympic Games was released seven years prior to the Games, including the main sustainability themes, different targets, from the rate of demolition waste being recycled to the reduction rate of drinking water usage, as well as responses and actions to fulfill those targets (LOCOG, 2007). Then, the Organizing Committee was the first one to get a certification for their sustainability management system. Finally, commitments for a low-carbon Games were further taken with the very first carbon footprint for Olympic Games being released (LOCOG, 2010).

Water management in London was already well-developed prior to the Games. The population had access to safe drinking water. Yet, an increasing number of people and industry in the city goes along with a rise in water demand. It is estimated that a quarter of the drinking water is lost due to leakage in the city (London Assembly, 2012). Additionally, climate change negatively impacts the water resources, with an increasing number of dry winters and hot summers which put pressure on the water supply. Besides, rainfalls become more intense and frequent, which constrains the capacity of the combined sewer of the city, built 150 years ago. As a consequence, still a great amount of untreated sewage spills into the river Thames, the main river crossing the city (London Assembly, 2012).

7.1.3 Rio 2016

Rio de Janeiro is one of the largest city in Brazil. It is characterized by socio-economic inequalities and high levels of poverty. The North region comprises the poorest areas of the city, while the South region is wealthier(Azzali, 2018). Rio was awarded host of the 2016 Games in 2009. It was the first time that the Games were hosted in South America, and the second time a developing country hosted the Games. Hosting mega-events was part of the city's strategy to rebrand its image of the city, as well as to enhance its development. The first step of the local government has been to invest public funding for urban renewal projects and then attract major sporting event. This way, Rio hosted the World football championships in 2014, and the Olympic Games in 2016 (Azzali, 2018). A special committee was created in 2008 in order to align the existing city master plan and the content of the Games' candidature file. This led to the creation of a plan called the "Urban and Environmental and Legacy Plan", which included the development of four Olympic Clusters and the regeneration of Porto Maravilha, the port area (Dupont et al., 2015). The Games were held in four different areas: Copacabana and Barra de Tijuca neighbourhoods located in the south of the city, in a high income area, and Maracana and Deodoro are situated in centre of the city, which is a lower income neighbourhood. A mix of existing (44%), temporary (21%) and newly built (34%) venues were used for the Games, and dispatched between the four areas of the Games (Schmedes, 2015).

New transport networks and new permanent infrastructures were built for the Games. Those new infrastructures include a transport system between Barra de Tijuca and the airport and the renovation of the airport. The Olympic Park, which includes some sports venues and the Olympic Village, in Barra de Tijuca, is located 30 km away from the city,was entirely built for the Games and is accessible by car or by BRT (bus rapid transit) (Azzali, 2018). The sustainability plan for the Games was built along the three usual pillars of sustainability, but called differently: Planet - People - Prosperity (Rio 2016, 2013). This plan is quite different than the one from London, as the plan for London had much more emphasis on the environmental pillar.

Rio faces strong water challenges and inequalities in terms of accessibility. It is a developing country where a part of the population lives on informal areas (slums), with no property right. This low income population lives on poor quality dwellings, which lack of basic services, including water supply and sanitation (Azzali, 2018). On the contrary, other parts of the city are well connected with the water systems. Another important issue is the lack of treatment of wastewater and the discharge of polluted water in waterways or in the open sea. This has led to the pollution of many sources of water around the city, including the sea and the main Bay of the city, Guanabara Bay. Water shortages are common in the city because either of severe droughts which have depleted the city reservoirs, and because some of the water sources are polluted (UNESCO and IANAS, 2015). Those considerations highlight the challenges faced by the Games' organisers and the local government when planning for the Games.

The presentations of the three case-studies highlight the different strategies taken by the Organising Committees. Besides, all the cities face different types of water challenges.

7.2 Olympic Games and water urban challenges

The findings presented in this section are the main elements which emerged from the cross-case analysis. The first part presents how the framework Driving forces - Pressure - State - Impact - Responses can be applied to Olympic Games. Then, each of the following parts present the responses to a specific challenges. A review of the responses for the driving forces is provided, and then water quality, water availability and climate changes are studied.

7.2.1 Including the Olympic Games in the DPSIR framework

First, it is essential to understand how the Olympic Games fit in the DPSIR framework of the urban water challenges. This part qualitatively presents what are the components of the chain affected by the staging of the Olympic Games and the components that can impede the staging of the Games.

In terms of driving forces, the staging of the Games in the city intensifies the sport tourism in this city for a short period of times - two weeks. This entails the need for new sporting infrastructures, and also results in a greater number of people living in the city during the Games. For Rio 2016, more than 500,000 athletes and tourists took part in the Games, which represents a rise by 8% of the population of the city during the Games. For London, the number of people attending the Games was even higher, with more than two million of visitors coming to the city (Dominiczak, 2012). This is an increase of 22% of the population in the city. Those numbers must be carefully considered, because they represent the number of visitors coming to at least one event of the Games, but they do not indicate whether those spectators stayed the entire period in the city. In terms of infrastructures, requirements from the International Olympic Committee are very specific. Approximately 30 sport venues are needed, including stadiums, indoor arenas and special sport facilities. Press pavilions, technical infrastructures and an Olympic Village are as well required to host the Games. If some of those infrastructures are built specifically, some others are retrofitted or used as they are.
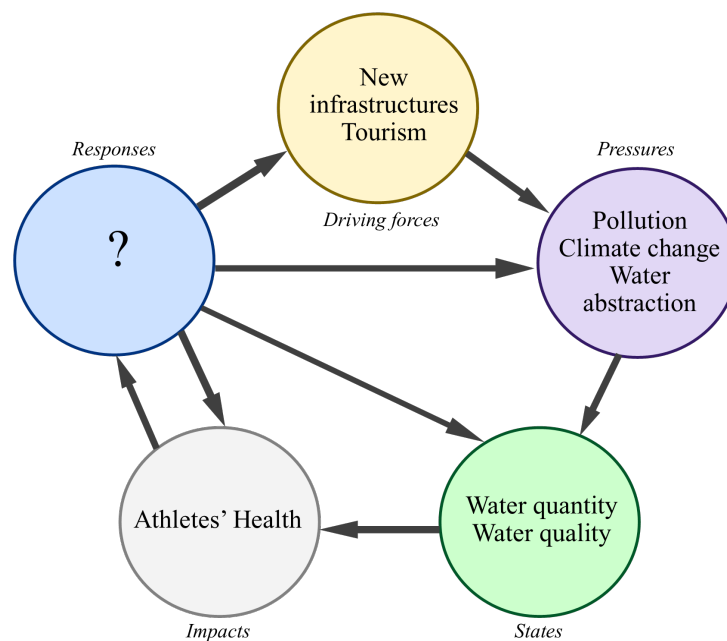

Figure 4: An example of DPSIR framework for water and Olympic Games

The pressures are the same than the usual ones presented in section 4.2 (i.e. pollution, climate change, water abstraction) but are even more exacerbated by the driving forces presented before. For instance, with the increasing number of people being in the city, more drinkable water resource is needed to be able to meet the needs of all the spectators and athletes. It has been estimated for the Games in Beijing a rise of 4.7 million m^3, compare with an annual water consumption of 3.4billion m^3, which represents an increase by 1.4% (Greenpeace, 2008). This then has an influence on the state of the environment, with the water quantity which is diminishing.

Finally, the impact component mainly contain the issues that can impede the staging of the Games. For instance, poor water quality can hinder the competitions occurring in open water, as it can have a negative impact on athletes' health. This occurred during the Games in Rio, where the water quality was very poor and some athletes got ill after being in contact with the water (The Telegraph, 2016). Even if those have not happened yet in any Games, episodes of drought could be an important issue, with water restriction measures that would be needed to be implemented. Floods could similarly threaten the staging of the Games.

This section presented how the Olympic Games fall within the DPSIR framework of urban water challenges. Only the Driving forces, Pressures, States and Impacts were reviewed. The next sections present the Response components.

7.2.2   Driving force mitigation

In the DPSIR framework, the responses can tackle all the other components of the chain, including the driving forces. Mitigating the driving forces can be considered as being an indirect measure to limit and reduce the impacts of the Games. As mention in the previous part, two main driving forces can be attributed to the Olympic Games, as presented in figure 6: the construction of new infrastructures and the growing number of people during Games time.

Since the first Games, back in 1896 in Athens, their size has continuously grown. From the use of seven venues back in 1896, to an average of 30 competition venues currently, the Games have become a mega-event (Long, 2013). But apart from those competitions' venues, many other buildings are needed – an Olympic Village, a media village etc. The IOC has decided after the Games in Sydney in 2000 to limit the number of athletes (10500) and sports (28) for the Games, in order to reduce the size but essentially the costs of the Games (Delaplace and Schut, 2019). This limit has contributed to restrain the gigantism of the Games. This way, there is a limit put on the water consumption.

Besides, there is an increasing use of either temporary infrastructure or existing infrastructures instead of new infrastructures. Figure 5 well shows this decreasing trend of building new permanent infrastructures for the Games. From a financial perspective, it is estimated that the use of temporary infrastructures reduces the cost by one third to one half compared to a new infrastructure (Long, 2013). Yet, there is a lack of study on the environmental impacts of temporary infrastructures, so more researches should be performed in order to know the extent to which the use of temporary infrastructures reduces the impacts on the environment, compared with new infrastructures. In fact, the areas where those structures are settled and the issue of reusing those structures are questionable.

For instance, the basketball arena in London was an entire temporary structure, including 12.000 seats, which cost was almost equivalent to the Copper Box Arena, a new permanent venue built for the Games in London. The basketball arena was dismantled after the Games and the whole structure was supposed to be used for other events. Yet, it is still for sale, and has not been reused yet (Smith, 2014). Regarding the water issue, the use of existing infrastructures is a way to keep the water consumption rate in the city at the same order of magnitude during the Olympic Games than the normal rate and avoid the rising of water consumption due to the building of new infrastructures.
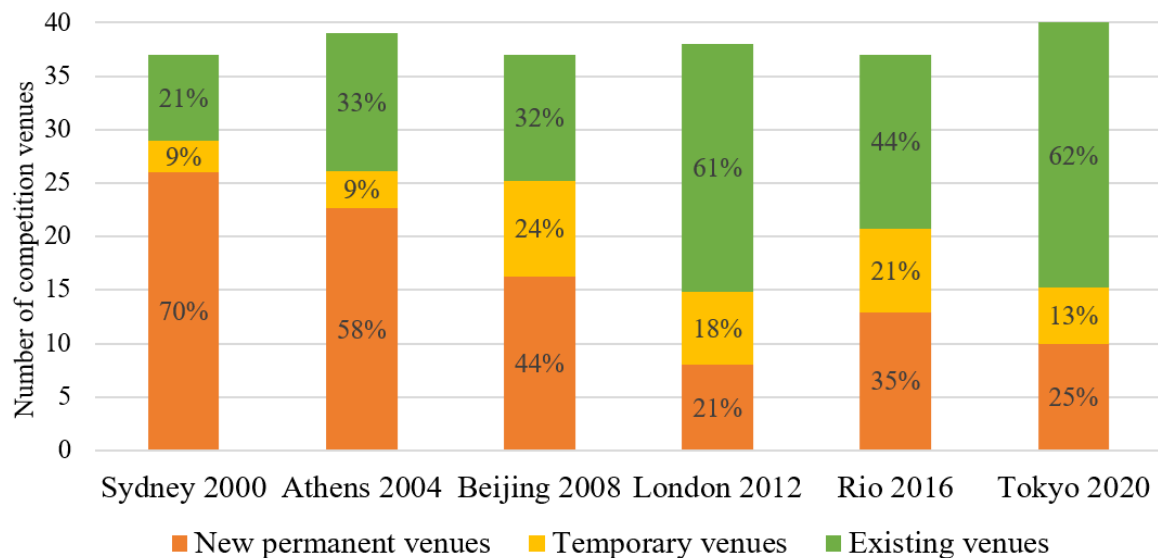
Figure 5: Evolution of the type of venues for the Olympic Games
Based on Schmedes (2015)

It can be more difficult to control the number of visitors coming for the Games, but this number is often limited by the availability of places to stay in the city during the Games, and the number of places at the competition venues. No major measures have never been taken to reduce the number of spectators coming to the city during the Olympic Games.

Figure 6: Examples of responses to mitigate the driving forces

7.2.3 Olympic Games and water quality

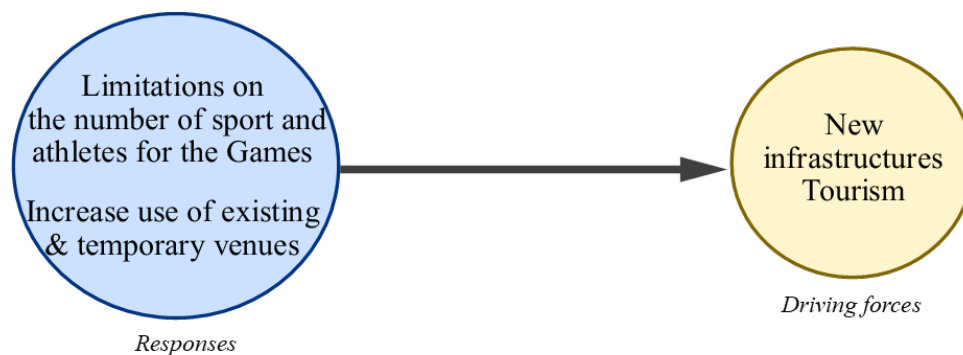This part presents and compares the main responses of the three Olympic Games to the water quality challenge. Two main types of responses are considered in this part. First the long term responses deals with the reduction of the pressure on water and the improvement of the state of the water quality. Second, the short-term responses deals with the mitigation of negative impacts.

Long term responses

First of all, it is necessary to know the main commitments related to the water quality challenge of the Games studied. Beijing was committed to increase the water quality of the main water reservoir of the city and to improve the treatment of sewage, in order to reduce the pollution of the water bodies in the city. Those commitments were part of an existing water management plan, developed years ago by the local governments (UNEP, 2009). London was committed to improve the quality of the river Lea, which is located just next to the Olympic Park. The improvement of this river was part the overall plan to redevelop and reduce the pollution on the area (LOCOG, 2007). Rio was committed to clean the Guanabara Bay, the main bay of the city, and other water bodies. This commitment was under the responsibility of the local state and government (Rio 2016, 2013).

It should be noted here that those commitments are more or less constraining. In Beijing and London, the failure would not have as much importance as in Rio, regarding the staging of the Games. In fact, improving the water quality in the Guanabara Bay was essential because it was one the area used for the sailing competition. On the other hand, the improvement of the water quality in the river Lea in London was just part of the regeneration of the neighbourhood. An unfulfilled commitments would not influence the staging of the Games.

Those commitments all relate to elements that are not especially built for the Games, but already part of the existing environment in the cities. This explains why those commitments are mainly related to the level of influence of the local government, and not on the hand of the Organising Committee.
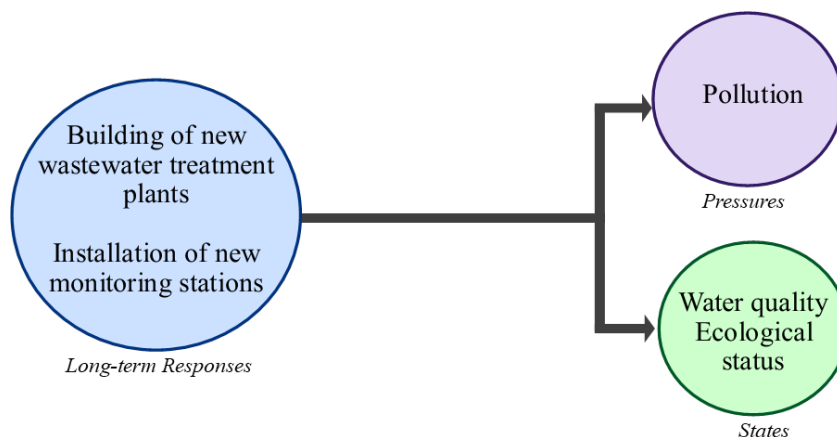
Figure 7: Examples of long-term responses to reduce the pressure and state related to the challenge of water quality

The main responses taken to fulfill those commitments are thus related to the improvement of water quality. It means that the pressure on water bodies, mainly different types of pollution, should be reduced. Some of the sources of pollution in the water bodies are the flowing of untreated sewage, or the solid waste pollution. Figure 7 presents the components of the DPSIR chain that are influenced by the long-term responses.

Table 3 shows the scores of each city towards the water quality challenges. Those scores highlight the success or failure of each Games' organiser towards the improvement of the water quality, for their respective commitments.

Table 3: Indicators scores for the evaluation of long-term response

Indicators	Components	Beijing 2008	London 2012	Rio 2016
Safely treated wastewater at Games Time in the host city(%)	Pressure	92%	100%	35%
Water quality at Games Time	States	Water reservoir 4	river Lea 3	Guanabara Bay 2

For the indicator water quality at Games time, a score of 1 indicates very poor quality, while a score of 5 indicates very good quality

Beijing

In Beijing, many measures to protect the water supply reservoirs of the city, including both surface and groundwater resources, were taken. Some of those measures include the establishment of protective zones in the surrounding of the catchment areas for surface sources or the installation of fences around the reservoirs. For groundwater sources, the focus was mainly on reducing the external pollution, and this was done by creating a protection zone around the groundwater recharge areas. Those measures started back at the end of the 1980's and have been gradually implemented (UNEP, 2009). This was a great success and the former polluted sources became usable again for water supply (UNEP, 2009). By taking proactive measures, anticipating the staging of the Games long before the bid, and integrating their water plan for the Games in their long-term water management plan, the local government fulfilled its commitments. That is why a score of four, representing a good water quality, was attributed to Beijing 2008.

The responses taken to achieve the engagement regarding the improvement of the sewage treatment in the city were first of all important investments made between 2001 and 2007 in order to increase the amount of sewage treatment plant, from four to nine. 92% of the sewage produced in 2007 in the city was treated (UNEP, 2009), compare with 20% in 1998. This example really shows how the Games can be used as a tool to speed-up the development of wastewater treatment plants. Those numbers really highlight that hosting the Games has really encouraged the local government to improve the wastewater treatment over the city.

London

In London, the Environmental Agency has monitored the quality of the river Lea for several years, with different variables, and the results prior to the Games used to show that the water quality was very low (UEL, 2013). Those waterways were polluted due to the presence of former polluting industries in the surrounding areas. Waterways infrastructures not anymore maintained, storm water from a pumping station discharged in the rivers, misconnection leading to sewage flowing into the river and road runoffs have led to years of contamination and fish-kill episodes (Patroncini, 2013). To improve the waterways, the measures taken were to repair the waterways infrastructures (walls etc.), to dredge and clean waterways and to repair the misconnection. The river banks were as well transformed into vegetated sloping banks (Jackson and Bonard, 2011). In 2015, three years after the Games, there were still a high concentration of dissolved oxygen in the water, which indicates poor water quality (Sánchez et al., 2007). There were also problems with rainfall events and road runoff which increase the amount of suspended materials in the water (UEL, 2013). Yet, no fish kills episodes occur after the Games and there was a great reduction of the amount of sewage being thrown in the river.

The results of the decontamination of the river are thus modest, and a score of three was attributed to London 2012 in terms of water quality at Games time. In terms of wastewater, London have an old and extremely developed wastewater management system. 100% of the water is safely treated in the city, and no further measures were taken prior to the Games regarding this aspect.

Rio

In terms of water treatment in Rio, the sewage collection system was expanded, with ten new waste water treatment stations built (Rio 2016, 2016a). Despite those new infrastructures, at Games time, only 35% of the wastewater was safely treated in the entire city. This number can be explained by the fact that there were no sewers to collect wastewater from the sources (household, business and industries) and bring it to the plants. One of the treatment plant, which was built in 2000, only started to treat water in 2014, because for 14 years it has not been connected to any sewage system. Also, most of the treatment plants do not work at their full capacity, for the same reasons (The Guardian, 2015). A lack of an effective water management plan prior to the Games period can explained those mismanagement.

Municipal and State Government of Rio de Janeiro, with other agencies, have planned for years to improve environmental sanitation of some of Rio's water bodies (Rio 2016, 2014). This was the main promise made in the bid for the Olympic Games, and one of the main reason why Rio was awarded the Games. For the Guanabara Bay, the improvement of its water quality is part of a plan started in 1990, the Guanabara Clean-Up Programme (Rio 2016, 2013). The Games were supposed to speed-up the plan and further improve the quality of the water and set a deadline for the plan. It included 12 incremental actions which were more or less implemented before the Games. One of the main action plan was to treat the untreated sewage that used to flow into the Bay. Eight treatment plants were supposed to be built near the Bay, according to the bid process, but only one has emerged (The Guardian, 2015). Around the bay, the sewage treatment has increased from 12% in 2007 to 50% in 2016, while the target was supposed to be 80% in 2016 (Rio 2016, 2016a). Even though this specific commitment has not been fulfilled, the amount of raw sewage being treated has really grown, and it cannot be said that the plan was a total failure. A score of two has thus been attributed to Rio regarding its water quality at Games time.

Some of the difficulties regarding the cleaning of water can be related to the fact that the sewage flowing in the Bay come from 16 different municipalities having their own practices and standards, so it makes it difficult to gather them around similar commitments and practices (Nolen, 2016). Additionally, problems of corruption occurred during the preparation of the Games, where is has been estimated that that two billion of dollars were lost due to corruption (Eduardo Suarez, 2016). In addition, the building of new infrastructures is not extremely popular in the city due to the need of expropriations and also because there is not an important public expectation to have their sewage treated (Nolen, 2016). All those reasons reveal the difficulties that the local governments face during the implementation of the Clean-Up programme. It further highlights how the local context is really important to understand the difficulty of the Organising Committee and local governments to introduce some of the responses planned. The action taken by the Organising Committee regarding the cleaning of the Bay was to installed new monitoring units to measure water quality in different places in the Bay.

Finally, in Rio, awareness campaigns were led in schools located nearby the Olympic Zones, in order to sensitize young citizens over the environmental management of water and the issue of water quality. Those awareness campaigns are a good way to indirectly reduce the pressure on the water bodies, yet the efficiency of such measures is difficult to gauge.

From the presentation of the long-term responses of the different cities towards water quality, it appears that the strategies were contrasted between the three cities. This can be explained by the fact that the commitments towards water quality were disparate as various types and sizes of water bodies were considered.

Short term responses

The presence of an unforeseeable event affecting the water bodies, or the failure of the response to improve water quality can lead to the implementation of last minutes measures. Those measures are essential for the staging of the Games, and for reducing the impacts of a poor water quality on the athletes competing in open water. Figure 8 presents the relation between short-term responses or mitigation measures that are used to reduce the impacts.
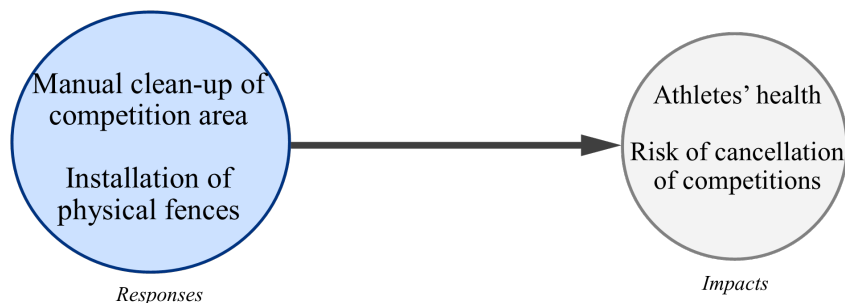

Figure 8: Examples of short-term responses to reduce the impacts related to the challenge of water quality

In Beijing, the focus for water quality was rather on the continuity of an already existing plan - the improvement of the water quality in the water reservoirs of the city - than on the implementation of new plan. Nothing was really implemented to improve the water quality of other water bodies in the city. There was an algae outbreak a month before the beginning of the Games, in June 2008 in the city of Qingdao, located in South Beijing, where the sailing competitions was supposed to be held (UNEP, 2009). A fence of more than 50 km long was installed in the sea in order to avoid the algae reaching the coasts and local inhabitants were requisitioned to clean up the coast (Greenpeace, 2008). All those measures were implemented to enable the sailing competition to occur in decent conditions, without obstacles for the competition (The New York Times, 2008). Untreated sewage, as well as rivers flowing in the sea, being contaminated by agricultural and industrial runoff, are important sources of pollution of coastal water in China, and this might have been the reasons of the algae outbreak (UNEP, 2009). Thus, reducing the pressure, such as the pollution, could have been carried out prior to the Games in order to ensure safe bathing quality, and avoid taking last-minutes measures to mitigate the negative impacts.

In Rio, despite the measures taken to reduce the pressures on the water bodies, water quality during the Games was heavily criticized. A year before the Games in 2015, 40 tons of dead fish appeared in the Guanabara Bay (Watts and Vidal, 2016). A great amount of untreated sewage, 65% of the total amount of sewage in the city was still flowing into the Bay. Many studies shown that the water in the Bay was a health threat for athletes, as well as Rio residents (Watts and Vidal, 2016).

Yet, the water quality in the Bay fulfilled the IOC recommendations, based on the standards of the World Health Organisation (WHO) (Rio 2016, 2016a). This was the case because the WHO based its water quality standard only on the presence of bacteria in the water, while a major study led by a team of Brazilian researchers analysed the level of viruses on the water (The Guardian, 2015). Illnesses from water activities are mostly related to the presence of virus in the water, and not based on the presence of bacteria. Those high levels of viruses originate from human waste in the water system, and it has been found in the Bay a concentration of viruses similar to the concentration found in raw sewage (Watts and Vidal, 2016). To avoid athletes getting ill due to the contact with the polluted water during the competition, athletes were vaccinated for viruses, and took protection measures during the race (Blount, 2016). Another issue, that has not been considered during the planning of the Games was the presence of floating rubbish in the Bay. Just before the staging of the Games, last minutes efforts were needed to have the site ready for the competition, as floating rubbish could damage the boats. A cleaning of the Bay was performed, and eco-barriers were installed across all the rivers flowing to the Bay in order to avoid solid waste flowing in the water (Rio 2016, 2016a). Then, garbage teams picked the trash from the river in large dumpsters. Specialized boats were put in the Bay, in order to remove trash, in relation with helicopters patrolling in the air in order to search for large pieces of trash (Niiler, 2016).

London did not have any issue in terms of water quality during the Games that would have affected the staging of the competition. This was due to the choice of the competition area, located in South England, related to the fact that the United Kingdom does not have any major issue in terms of water quality in its surrounding seas.

Barriers and positive elements

All the Games organisers committed to improve water quality of either rivers, sea or water reservoirs. Yet, it appears that none of them really succeeded in achieving their commitments, except Beijing. It was especially a failure for Rio 2016, which promise on the cleaning up of water bodies was not delivered. Combining the long and short term responses, the main reasons of the lack of success are:

- **Too ambitious challenge**
  This was the case for Rio, which has claimed that the local government would improve the water quality of the Guanabara Bay in seven years. The plan for cleaning the Bay was established back in the 1990's, and in 20 years, few measures were taken, so the local government has been very optimistic to say that the Bay would be cleaned in seven years. In fact, even though the Games bring financial investments and a great dynamic in the city, the financial, cultural and political context can diminish this dynamic.

- **Occurring of unforeseeable event preventing the competition to be held in safe manner**
  The algae outbreak in Beijing prior to the Games is a great example of an unpredictable event. Last-minutes measures had to be taken, and the sailing competition was held in safe conditions, but this event generated a negative public image of the Games. Yet, it can be argued that the staging of the Games had positive impacts, as it had probably sped-up the cleaning of the sea, and one can wonder whether it would have been cleaned that way if the Games were not held.

- **Tight timeframe**
  The fact that only seven years occur between the winning of the bid and the Games makes the timeframe very short to fulfill some commitments. In London, the water quality improvement of the river Lea has not really been a success, but this assertion was made with data retrieved during the staging of the Games. One can thus wonder whether the quality could be better if a longer timeframe was considered, for instance with measures done this years, so eight year after the Games.

- **Lack of investment by the local authorities**
  Even though the local authorities participate in the planning of the Games, and are responsible for some of the commitments, their lack of investment can prevent them from respecting their engagement. This was especially the case in Rio. The lack of transparency on how the financial resources allocated for sanitation prevented the efficient implementation of long-term strategies. The state and city of Rio were in financial crisis in 2015. Many city employees were fired, and public services were neglected for years. The federal government injected $900 million dollars, but this money was only used to prevent mass chaos during the Games. The clean-up of water bodies was not anymore a priority, from a financial perspective (Trendafilova et al., 2017).

- **Lack of comprehensive water management plan**
  The example of wastewater treatment plants in Rio being built but not functioning due to the lack connecting pipes shows how the lack of water management plan can create a lot of mismanagement. This can be explained by a lack of efficient and permanent public policies in terms of sanitation in the city and the setting up of short term actions against the establishment of long-term strategies, which limits the creation of an effective water management plant (The Guardian, 2015).

Some positive responses and dynamics towards the improvement of water quality can nonetheless be retrieved from the analysis of the three cases.

- **Increase the wastewater treatment in the host city**
  The Games in Beijing showed that it is possible to really improve the wastewater treatment in the city with the building of new wastewater treatment plants and the extension of the sewage system as part of the Olympic Games. This was possible due to an important financial investments of the local authorities, and the absence of any challenges related to the local context, on the total opposite side of the situation in Rio.

- **Integration of existing water management plan**
  Some host cities integrated the existing urban water management plan into the bid and commitments for the Games. For instance, in Beijing, the strategies of the Games organiser's and local municipalities were in line with the overall urban water strategies of the city, started back in the 1990's. The Games has been used here to speed-up the development of the management plan.

- **Increasing number of monitoring stations for water quality**
  New monitoring stations are often installed prior to the Games in order to control the water quality of the competition venues. This was the case in Rio, where the Organising Committee invested in new water monitoring units in the Guanabara Bay. Those stations are not to be used only for the Games and still function after the Games. This provides a great legacy for the city. To go further, monitoring stations could be installed in water bodies other than the ones used for the competition, in order to further promote the monitoring of the water quality.

- **Awareness program on water quality**

  Only Rio has conducted awareness program for local citizens regarding water quality, and even though it is difficult to know the efficiency of such program, they should be promoted and largely used by future Organising Committees. An additional public to include in the program could be the visitors of the Games.

- **Release of a new water quality guidelines**

  After the polemic on water quality in Rio, the International Olympic Committee has released a water quality guidelines for future Games organisers (IOC, 2017a). These guidelines establish a framework for a positive long-term approach towards water quality. It mainly includes new standards, including testing timelines and on-site inspections. The reasons for setting up this standard are several, including the reduction of risk of competitions' cancellation and the reduction of the negative media coverage (IOC, 2017a). This example reveals how the IOC reacts to environmental negative image of the Games through the creation of new guidelines for host city, in order to mitigate the negative impacts. Yet, as those guidelines were created three years ago, they will be first applied for the Games in Tokyo in 2021, so it is not yet known whether those guidelines will really change the story.

Those positive dynamics between water quality and Olympic Games highlight some of the specific responses improving the water quality in the host city. Yet, great efforts must be pursued in order to ensure that the commitments taken during the bid are fulfilled and that proactive measures are taken in order to avoid any negative impacts.

7.2.4   Olympic Games and water availability

This part presents and compares the main responses of the three Olympic Games to the water availability challenge. The main objective, as presented in figure 9 is to reduce the use of potable water, to further diminish water abstraction, which is a pressure on the environment, and then increase the water quantity available, which represents the state. Two main strategies are considered in this part: the saving and the reuse of water.

Overall, the analysis of the different responses towards water availability showed that those responses are mainly implemented at the infrastructure level. It means that only the infrastructures built for the Games, the Olympic Park, the Olympic Village or any other new buildings are part of the responses. This implies that no important responses towards water availability are taken at the scale of the city. This is probably due to the fact that those responses mainly rely on technological elements installed in those new infrastructures. The building of those infrastructures mostly relies on the Olympic Delivery Authority, but the main sustainable commitments are expressed by the Organising Committee. The growing use of green certifications for new buildings by the organisers of the Games has promoted and make the use of water savings and water reuse technologies extensively applied in new buildings.

One of the main indicator that is used by Organising Committee and that is considered in this analysis is the percentage of water savings in new permanent venues. It represents the percentage of water that is saved in the new buildings especially built for the Games. Those new buildings include for instance the new competition venues as well as the Olympic Village.
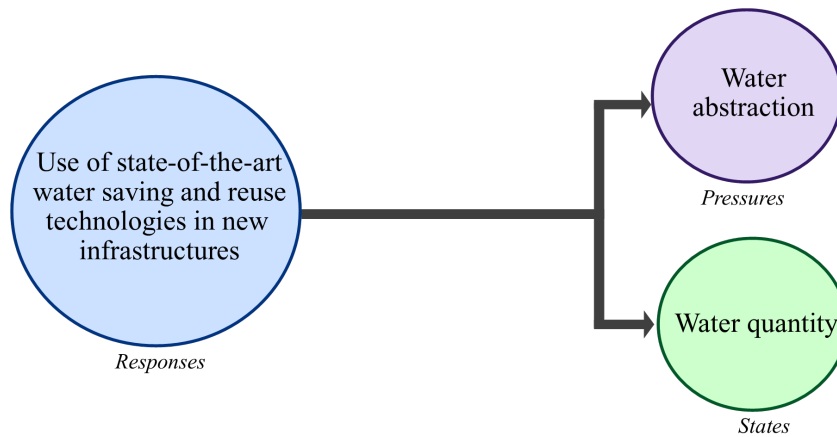
Figure 9: Examples of responses to reduce the pressure and state related to the challenge of water availability

A reduction target can be settled prior to the Games in order to fix the percentage of water that should be saved in the new venues using different technologies. For instance, London 2012 set in its sustainability plan that the demand for water in new permanent venues should be reduced by 40% compare with the 2007 standard (LOCOG, 2007). On the contrary, Rio and Beijing did not define any water savings target prior to the building of the Games. Table 4 presents the scores of each Games studied in this report towards the percentage of water savings in new venues. It appears that Beijing and London have the same percentage, 40% while for Rio this percentage is a bit lower. This could, in a way, indicate that Rio did not take as much measures as in Beijing and London, but the standards used to compare water savings are different between the Games. The numbers should thus be carefully considered, and the comparison between the Games cautiously viewed.

As mentioned in the section 7.2.2 on the mitigation of driving forces, the number of new venues is decreasing, with the increasing use of temporary or existing venues. From the reports studied for the three Games studied, it appears that no measures were specifically taken for water savings in temporary or existing venues.

Table 4: Indicators scores for the evaluation of water availability

Indicators	Components	Beijing 2008	London 2012	Rio 2016
Water savings in new permanent infrastructures(%)	Pressure	40%	40%	30%

Water saving schemes
All the sustainability reports from the three Games highlight that all the new permanent venues were built with water savings technologies, including low flush toilets, low flow taps and low flow shower (UNEP, 2009; Jackson and Bonard, 2011; Rio 2016, 2014). It is nonetheless difficult to know the efficiency of those water saving technologies, and how those technologies were chosen. In London, a presentation day was held, during which companies developing modern and new water savings technologies presented their products, in order to guide the choice of the Olympic Delivery Authority towards which technologies should be used (Jackson and Bonard, 2011). The lack of transparency towards the specific costs associated with each technology and its efficiency makes the analysis difficult. Indeed, it is then difficult to know which type of technologies has been used: the most costly but the most efficient? The less costly? Or a balance between both?

Those questions still need some answers to really understand the strategies of the Olympic Committee. Yet, the use of these technologies has a limit and does not enable to save a great amount of water. In fact, for London, only 18% of water savings could be achieved using water saving technologies in new permanent venues (Jackson and Bonard, 2011). To enhance water savings, other means were thus needed especially because London had a target of savings 40% of water in new permanent venues.

Water reuse

In order to further enhance the reduction of water use, apart from using water saving technologies, the promotion of water reuse can be implemented. The water reuse technologies can be based on three different types of water: rainwater, greywater or treated sewage water. Most of the time, those types of water are reuse for non-water usage: irrigation, toilet etc.

Use of rainwater

First the catchment and reuse of rainwater is a widely spread measure in new urban spaces created for the Games, mostly the Olympic Park and Olympic Village.

In Beijing, the rainwater was captured for irrigation and to boost the waterflow in waterways. It has been estimated that 95% of the rainwater was reused in the Olympic Park (Greenpeace, 2008). This water was mostly collected with permeable bricks and collectors on the roof of the venues (Salcines et al., 2013). Most of the new permanent venues, as well as refurbished venues had rainwater collectors, and a recycling station was integrated in some of those in order to use the rainwater onsite, including for cleaning or fire-fighting (UNEP, 2009). Beijing also installed rainwater collectors in the streets across the city (Greenpeace, 2008). London similarly used rainwater collection in its Olympic Park and Olympic Village.

Use of treated sewage water

Likewise, sewage water can be treated and reused for non-drinking purpose. Yet, the treatment of sewage water is much more complex, as more polluted than greywater or rainwater. In Beijing, a biological sewage water treatment plan has been built on the Olympic Village, where water was then reused for irrigation or toilet flushing (LOCOG, 2007). In London, the first blackwater treatment plant for water reuse was built in the Olympic Park. It was the first time that this specific technologies was constructed in the United-Kingdom. It takes sewage water from London' sewers and treat it. Then it is used for toilet flushing, irrigation and for the energy centers of the Olympic Park. A great amount of new knowledge and practices was needed in order to make this first treatment plant working effectively Ali and Sarah (2015).

Awareness campaigns

Awareness campaigns are led in order to promote water savings and water reuse measures. Those campaigns were widely pursued in Beijing, tackling the entire city. Households and industries were encouraged to use the water more efficiently in order to reduce the stress on local water resources. In London and Rio, no specific campaigns has been led, but the three Organising Committees tried to raise awareness of athletes, visitors and spectators with water savings campaigns during the Games in the sport venues and Olympic village.

Improve access to potable water

Apart from the water savings and water reuse, water availability deals with the access to potable water in households. In fact, water accessibility still needs to be upgraded in many countries over the world. This aspect was included in the bidding file of Beijing and Rio. In Beijing, the city upgraded three major drinking water treatment plants to provide potable water for three million of people, representing a rising of 15% of the population having access to potable water (UNEP, 2009). However, even though water quality was high at the treatment plants, the quality was much lower at houses due to the type and age of materials used for water pipes. Another measure was thus to change some of the pipes in order to have a higher drinking water quality at households (Greenpeace, 2008).

In Rio, the main commitment towards water accessibility was to bring water supply in areas where new infrastructures were built, so mostly in the area of the Olympic Village and Olympic Park (Rio 2016, 2014). The commitments were fulfilled because water was available there during the Games. Yet, nothing was done to improve water supply in other parts of the city, like in favelas or other poorer areas. In this way, it can be said that the Games did not improved the water accessibility in the city.

Barriers and positive elements

From the presentation above of the main findings related to water availability responses for the Games, it can be said that most of the Games took measures and actions in order to decrease the pressure (water abstraction), and thus the state (water availability). Yet, different levels of achievement can be observed. Beijing seems to have achieved a lot in term of water availability in the context of the Games, this can be explained by the fact that among the three cities, Beijing is the one which has the highest water stress. London as well has used the Olympic Games to introduce new practices for water reuse.

The main negative dynamics or missing points are the following ones:

- **Absence of initiatives for existing and temporary infrastructures**
  As mentioned previously, none of the Games has done anything for the use of water on temporary and existing infrastructures. In fact, some of the existing infrastructures are retrofitted to host the Games, mostly in order to fit with the technical requirements from the International Olympic Committee, but nothing is said on whether the water systems are improved in those existing buildings. Additionally, no measures were taken for the water use in temporary infrastructures, in spite of the fact that those infrastructures would need some specific installations to get water. With the growing use of temporary and existing infrastructures, the Olympic Committee should first improve their knowledge on water consumption in existing and temporary infrastructures, and then include measures to sustainably manage water in those infrastructures.

- **Initiatives limited to new Games' infrastructure**
  The measures and responses towards water quantity taken during the preparation of the Games were limited to specific areas, most of the time Olympic Park and Olympic Village - except for Beijing, which installed rainwater collectors across the city, and which led campaigns in the entire city to promote water savings through efficient technologies. This restriction limits the positive impact that the Games can have on urban water availability. Most of the time, state-of-the-art solutions were only used for the new infrastructures, but those solutions should be widely promoted in the city.

- **Lack of transparency**
  The choices made by the Delivery Authorities of the three Games on the types of water saving technologies, their efficiency and their costs are not very transparent, and more details should be provided on how the choice for a specific technology is made.

The main positive and effective measures are:

- **Widespread use of water savings technologies**
  The use of water saving technologies in new permanent venues appears to be a widely spread measure. The fact that the Games organisers try to get certification for their new venues can explain why such measures are implemented, as those certifications include requirements for water consumption and water saving.

- **Awareness campaigns for water savings**
  A common measure that was identified for the three Games is the awareness campaigns led on the rational use of water in competition venues, and other infrastructures specific for the Games, like the Olympic Village.

- **New sustainable initiatives**
  The implementation of the first sewage water reclamation plant in the Olympic Park in London is one example of how the Games are stimulating sustainable practices. Ali and Sarah (2015) show that this implementation has created substantial learning in the United Kingdom for future water reclamation plants. Another example of the introduction of new sustainable initiatives is the LEED certification of the Olympic Village in Rio, which was the first neighbourhood to be certified LEED in Brazil.

7.2.5 Olympic Games and climate adaptation

Climate change entails many negative impacts on the environment, which are even more exacerbated in cities. The responses in this part thus deal with the mitigation and adaptation to climate change impacts. Two main types of impact are considered in this part, as shown in figure 10: the flood risk on one part, and the heatwave and drought mitigation on the other. The main responses are taken at the scale of the infrastructures built for the Games and the entire city does not benefit from it.
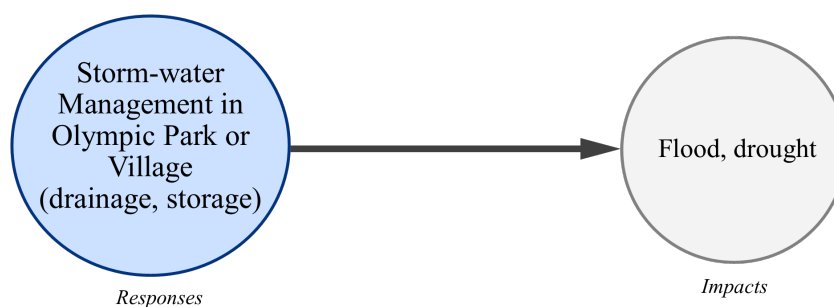
Figure 10: Examples of responses to reduce the water-related impacts of climate change

The responses heavily depend on the situation of the city towards climate change. In London, the most important challenge is the flood risk, and the flood management. In Beijing, the main issue deals with the growing amount of dry periods over the year. In Rio, the number and intensity of heat waves has grown over the years and there is a high risk of flood. Heat waves, droughts and flooding can all occur during the Games, as they are held in Summer. For the moment, none of the Games has experienced such a climate-event, but the future Organising Committees should be prepared to fight such events.

In Beijing, no specific measures were taken for climate change adaptation. To reduce the negative impacts of an increasing number of droughts, the recycling and use of water-saving technologies, presented in the former section were the main contributions towards climate change (UNEP, 2009). In London, a strong focus was put on storm water management. The Olympic Park was designed in order to tackle a 100-year flood event and to face the rising frequency of heavy rainfall events. First, the overall design of the new Olympic Park considered the risk of flooding from the river Lea, by removing thousands of properties which were located near the river. Then specific infrastructures for flood protection and to manage rainfall events were built, including flood storage and a specific drainage system for rainwater (Jackson and Bonard, 2011). As no major rainfall event or flooding have occurred yet in London, it is not really possible to say whether the responses taken are efficient or not. In Rio, no specific measures were taken regarding the water-related impact of climate change.

The responses to mitigate climate change urban impacts appear to be at an early stage in the Olympic Games responses to enhance water sustainability. Again, this really depends on the urban climatic context and on the current state of the city towards water management. If London was able to invest in climate change infrastructures in the Olympic Park this was probably due to the advanced situation of London towards water management, with already performing infrastructures, while the priority in Rio was more to increase the number of water infrastructures in the city.

7.3   Recommended initiatives

This section presents the main initiatives to be recommended that emerged from the analysis of the cross-case study. Those recommendations do not aim to be applied to all the Games, as the urban and socioeconomic context is quite different from one city to another. Rather, they should be used as guidelines for designing the master plan of the Games, as well as defining the sustainability objectives. Those initiatives were identified using the cross-case studies, through the identification of the efficient, unsuccessful and missing responses towards water sustainability. This section is divided into two main parts, which represents the two main groups of actors that should receive the recommendations. The first part of the recommendations is to be applied by the Games' organisers. The second part mainly focuses on initiatives which could be implemented by the International Olympic Committee.

7.3.1   At the Scale of the Games' organisers

In this first part, the recommended initiatives are addressed to all actors involved in the design, planning and staging of the Games. Those actors include specifically the company responsible for the bid procedure, the Organising Committee for the Olympic Games as well as the Olympic Delivery Authority and the local governments. Two main types of recommendations are given in this part. First, technical solutions to improve water quality and water availability, in order to reduce the pressures on the state of the environment are provided. Then, recommendations related to the governance of the Games are presented.

Initiatives related to technological solutions

- Certify all the new buildings with green building certifications. Those certifications ensure that state-of-the-art water saving and reuse technologies are promoted. An assessment of the current market on water saving technologies, in addition with the consideration of the life-value and not only the costs of the technologies should be promoted.

- Start considering to get environmental certifications for existing and temporary venues, in order to ensure that those venues participate as well in the strategies towards water saving and reuse.

- Promote the use of new and innovative technologies for new infrastructures, as well as for other parts of the city that does not benefit from the Games. The Games provide an unique opportunity to build, often from scratch, a urban area, by bringing financial opportunities. Those two factors make the development of new systems, that could not have otherwise been built in another context, extremely relevant.

- Continue awareness programs for environmental challenges. Those programs were widely promoted during the last three editions, especially regarding the rational use of water resources.

- Consider a wider integration of solutions for climate change mitigation and adaptation in the master plan of the Games. The Games studied had really few measure towards climate change adaptation. Yet, climate change will be an upcoming challenge for the future Games, especially because the Games are held during the warmer months in Summer in most of the host countries.

Initiatives related to the governance part

- Set clear sustainability objectives at the beginning of the project, with measurable targets. This is essential in order to increase the transparency towards the achievement of those objectives. This measure would also enhance the sustainability management as it is often argued that measurable goals should be formulated in order to manage sustainability (Ciegis et al., 2009).

- Integrate as much as possible already existing urban development plan in the design of the Games. It means that the design of the Games should as much as possible follow the main development axis of the existing urban plan of the host city, including the water management. This is needed in order to ensure that an appropriate accordance between the urban development and the development needed for the Olympic Games.

- Encourage all the developers to engage in the sustainability initiatives settled by the Organising Committee, in order to ensure that the Games are effectively built in safe and sustainable manners.

- Encourage the release of data regarding the environmental performance of the Games. The analysis showed the difficulty of assessing the environmental performance of the Games. This initiatives would raise public awareness over the environmental impacts of the Games.

- A focus on the long-term legacy of the Games should be preferred over short-term measures. This is necessary in order to reduce the pressure before the occurance of any negative impacts.

7.3.2 At the scale of the International Olympic Committee

In this second part, the focus is on the International Olympic Committee. As this international organisation is at the head of the celebration of the Olympic Games, and sets the requirements for the Games, it is relevant to propose some initiatives that could improve the current situation. Those new initiatives could be implemented as new requirements for the Organising Committee, and some of them could be added in the Host City Contract.

- Enforce the fulfillment of sustainability commitments. The host city commits to many objectives towards sustainability in their bid process, that are sometimes too ambitious to be fulfilled, such as the clean-up of the Guanabara Bay. The introduction of penalties in case of non-compliance could make the host city reconsider their sustainability objectives by proposing a more realistic and feasible plan.

- Set specific requirements for sustainability objectives. Those requirements could be for instance a minimum goal to achieve. For instance, the International Olympic Committee could set requirements for a minimum water savings requirement in new permanent venues.

- Increase flexibility towards choice of venues. This initiative would reduce the risk of competitions' cancellation. The examples of Beijing and Rio doing a last-minutes clean-up of their sailing competitions highlight the need for the organisers to have back-up options. If the clean-up were successful in those cases, one can wonder what would have happened if the venues were still too polluted after the clean-up. In this case, it should be possible to change the competition venue, in order to ensure the staging of the competition.

- Change the guidelines for the water quality in competition venues. This would be needed in order to integrate the measurement of the levels of viruses in the water, and not only of the levels of bacteria.

- Make the certification of new permanent infrastructures mandatory. To some extent, this would ensure that those new infrastructures are built with modern water-saving and reuse technologies. In order to provide flexibility, each Games' organisers could choose the green certification that they want to use.

8 Discussion

This chapter first discusses the roles of the Olympics in the promotion of environmental sustainability in the host city. Then, the limits of the project are reviewed and a presentation of other approaches that could have been used is made. Finally, a reflection on the current challenges and future perspectives on sustainability and Olympic Games is provided.

8.1 Enhancing environmental sustainability: a new role for the Olympics

This first section presents insights on how the Olympic Games can be considered as a tool for innovative and sustainable urban development based on the analysis. Then, the generalization of the results found for water sustainability to other sustainability dimensions is discussed.

8.1.1 Olympic Games as a tool for innovative and sustainable urban development

Olympic Games appear to be used as a tool to enhance water sustainability. The responses used seek to reduce the pressure on water (i.e. the pollution) and to improve the state of water in the city (i.e. quality and quantity). Overall, according the DPSIR framework, those measures are indirect ways to reduce the negative impacts of both Olympic Games and already existing water-related urban impacts.

Development of new water related infrastructures

The analysis showed that most of the time, the Games are used to develop new and modern water infrastructures in the host city and region. Two main strategies of development were identified with the multi-case study.

On the one hand, Rio and Beijing mostly focused on the upgrading and on the building of new water infrastructures: sewage treatment plants and sewage networks. In developing countries, where water accessibility and water treatment are still limited, the focus with the Olympic Games is thus to improve the water sanitation in the city. This development of new infrastructures is often part of an already existing water management plan, and the Games are then used as a way to increase the financial investment for those new infrastructures. The dynamics created by the hosting of the Games further make the construction of new infrastructure easier. Improving the sewage collection and treatment reduces the flowing of untreated sewage in the surrounding water bodies that are polluted. With new wastewater treatment plants, a smaller amount of untreated sewage flow into surrounding areas, and then the pressure on those water bodies is lowered.

On the other hand, as London mostly focused on the regeneration of a specific neighbourhood in the city, most of the responses were taken towards this area, and nothing was done at the scale of the city in terms of water related challenges.

Overall, those new infrastructures aim at increasing water quality and the environment in the city, and therefore it can be argued that Olympic Games participate in the urban sustainable development of the host city.

Olympic Games as accelerator for urban development

One can argue that the implementation of the management plan, and the construction of new water related infrastructures would have anyway occurred in the city, even though the Games were not held. This is probably the case for the development of infrastructures for water sanitation, but one can wonder how much time this would have taken without the staging of the Games. In the literature, there is a lack of study on what happen when the bid of a candidate city fails, and whether the development plan proposed in the bid is still considered or not afterwards.

Olympic Games are used as a tool to accelerate existing development plan, both on the small scale - the regeneration of a specific neighbourhood, like in London, or the development of the water management plan of the city. In Beijing, the development of water related infrastructures was part of the water management plan developed back in the 1990's and would have been implemented even without the staging of the Games. One can argue that staging the Games really accelerated the development of the infrastructures, with the increasing pace of construction for wastewater treatment plants from 2000 to 2007, just during the period prior to the Games, when one plant was built every year (Greenpeace, 2008).

This catalyst aspect of the Games can be explained by different reasons. The first reason is the financial aspect. The Games ensure important financial investments from different actors directly to local governments and stakeholders of the Olympic Games. This was especially the case for London, which mayor argued that the Games would bring the government to financially invest in local projects, and thus accelerate the construction of development plan already existing before the Games. Then, the fact that the planning and preparation for the Games are really different from normal planning procedures can provide a positive dynamics for the local government to accelerate their development plans. This difference is mostly explained by the fact that no delay can be accepted for the construction works. Indeed, there is a fixed date for the Games, and deadlines must be respected in order to ensure a staging of the Games on time. Thus, some planning procedures can be sped up or made not mandatory. Finally, the media coverage and international broadcast of the city often motivate and push the local government to try and show its worth. This motivation was especially behind the bid of Beijing for the Games in 2008. The national and local governments really wanted to show that the city of Beijing could compete with other cities from developed countries, and promote the quality of life in the city (Zhou et al., 2012).

Olympic Games as an innovation lab for new practices

This project showed that new sustainable practices emerged with the Games. First of all, the fact that specific sustainability targets must be fulfilled, and that some buildings are getting green certifications, increase the use of state-of-the-art water savings and water reuse technologies.

This was especially the case in London, where the first blackwater treatment plant in the United-Kingdom - treating sewage to be reuse for non-potable use - was built in the Olympic Park. It was constructed to be used during the Games and for the legacy. New practices and knowledge were needed in order to implement this innovative system. However, there is a lack of evidence on whether this practice has spread in the United Kingdom after the Olympic Games.

In terms of tools, the Olympic Games promoted the use of building certifications in Brazil, with the Olympic Park being the first neighbourhood to get a green certification. Those types of certification ensure the implementation of water savings and reuse technologies, and thus are a way to implement the concept of sustainability in practice. In this case, there are evidences of Games as a learning process. First of all, this implementation enhanced the relations between Green Building companies and sports stakeholders, including the IOC and other event organisers. They started to consider the use of green building certifications for their own events. Additionally, internal learning and new practices with the municipality of Rio was experienced. New internal measures in the Municipality of Rio were implemented afterwards in terms of green building - involving the inclusion of guidance and practices and the need to not only consider the cost during the construction project for administration venues, but the overall life-cycle stage. This way it can be said that the Games enabled the introduction of new regulations and practices in the host city (Faria, 2016).

8.1.2 Generalization of the results for the other sustainability themes

The analysis studied the dynamics behind urban water sustainability and Olympic Games. Yet, as mentioned in chapter 5, other urban sustainability dimensions are affected positively or negatively by the Olympic Games. Those dimensions are the transport, infrastructure & venues, energy, climate change, resources, waste and natural environment & biodiversity. One can thus wonder whether some of the results found and proposed initiatives can be generalised to the overall environmental sustainability of the city. Concretely, to know whether the recommendations found regarding the water challenges could be applied to other dimensions. This part presents an overview of some of the dimensions, and how the findings could be appropriate for the other sustainability themes.

Overall, the setting of clear sustainability objectives applies to all the sustainability dimensions, as well as the public release of specific environmental data. Enforcing the fulfilment of sustainability commitments as well as setting specific requirement for sustainability objectives would as well be beneficial for all the dimensions. The growing use of green building certifications and the implementation of certifications for existing and temporary buildings can positively affect many other different sectors such as the energy, the resources, the infrastructures or the biodiversity. Awareness campaigns and programs could also make a change for some of the other sustainability dimensions, for instance the energy with campaigns for the reduction of energy use, the promotion of green transport, recycling programs for waste management etc. As well, the promotion of the use of state-of-the-art technologies can be done within each sustainability dimensions. More studies would be needed for the biodiversity, because there is still a lack of work on this specific dimension. This dimension is in fact quite different from the other ones, because the Olympic Games mostly have negative impacts on it and there are few evidences where the Games effectively enhance the biodiversity. The construction in Rio of the golf course on a protected site or the use of temporary venues on green areas like in London in 2012 are examples showing how the Games can have negative impacts based on decisions made during the planning phase.

The initiatives identified for the water quality challenge appeared to be quite general and can be applied to other sustainability dimensions. Yet, it it still needed to dive into each dimensions in order to understand more thoroughly the underlying dynamics of the responses of the Games' organisers for each specific dimension.

For instance, the analysis of the energy sector could be interesting and is quite similar to the water sector in terms of structure of the analysis. The main objective would be to reduce the energy consumption, and to use clean energies. The Driving-Pressure-State-Impact-Response could easily be applied to the energy dimension, with the same driving forces as the ones used in this project, but other pressures, states and impacts. Then, like for the water challenges which heavily depend on the local context, measures taken in this sector highly depend on the local energy mix in the host city. For instance, Brazil is characterized by its high share of renewable energy with a large amount of hydropower. On the other hand, Beijing in 2008 mostly relied on the use of coal or other non-renewable resources for energy production. This difference might create disparate strategies towards the energy sector during the planning of the Games. Another interesting point would be the use of renewable energy for the Olympic Games. London was committed to use 20% of renewable energy produced onsite in the Olympic Park, commitments which was not fulfilled as none of the energy consumed was based on renewable energy. It would be interesting to understand the reasons behind this failure. The example of the energy sector shows that generalisation should be carefully conducted, and much more research for each sustainability dimensions is needed, in order to provide tailored and specific initiatives.

Another question is whether the three main reasons why the Olympic Games appear as a tool for innovative and sustainable urban development could be applied to the other sustainability dimensions. It can be nonetheless said that the Games participate in the development of new and modern infrastructures in the city for some of the sustainability dimensions. It has been widely studied that the Olympic Games enable the development of the transport networks in the host city (Hensher and Brewer, 2002; Zhou et al., 2010). More research would be needed to have precise examples and practices for each sustainability dimensions.

8.2 Reflections on the project

This second section presents reflections on the project by first discussing the limits of integrating the concept of environmental sustainability within the Olympic Games. Then, some methodological limitations are discussed, and finally other approaches that could have been relevant for this project are presented.

8.2.1 Limits of integration of sustainability in Olympic Games: Greenwashing?

The analysis showed the limits of creating sustainable Olympic Games, especially regarding the water challenges. This part tries to highlight the main issues regarding the achievement of sustainability during Olympic Games.

Distance between bid commitments and reality

There is sometimes an important gap between the commitments made in the bid, the measures taken afterwards and the final results. This goes in line with the observations from Gaffney (2013) who also highlighted a distance between the bid and the reality. One can thus wonder if the sustainability commitments and actions presented in the bid are only hollow promises, for the International Olympic Committee to adhere to the project, and win the bid. Commitments are often afterwards either scaled down or even "forgotten" during the planning of the Games. In fact, the IOC is increasingly sensible towards sustainability engagement in the bid, and it is widely agreed that Rio won the bid for the Games in 2016 mostly because of their commitments to revitalise the water bodies, commitments which were partly fulfilled.

Additionally, the competition between candidate cities during the bid process sometimes makes the cities pledge for unrealistic or unattainable targets, just to appear better than the other. Yet, when the bid is won, the Organising Committees really struggle to fulfill those targets and some of the commitments cannot be achieved. This highlights the need for the International Olympic Committee to take measures in order to ensure that the commitments made in the bid are really implemented and that the Organising Committees really walk their talk.

Short-term measure to reduce the negative impacts
Some unforeseeable events, or the incompleteness of the planned measures sometimes raise the need to focus on short-term actions in order the reduce the negative impacts. This was observed during the 2008 Games in Beijing, after the algae outbreak and in 2016, with the last minutes physical clean-up of the main bay of the city in Rio. Those measures were taken in order for the sailing competitions to be held in safe and sanitary conditions. But those actions seek to reduce the impacts and not the origin of the problem. In those cases, those actions are not part of any positive environmental legacy, as the clean-up only benefits the water bodies for a short period of time, and after this period, the problem will occur again. This demonstrates the limit of the environmental actions taken during the Olympic Games that are taken to give a positive image of the city for the Games but are not part of the environmental legacy.

Other striking examples for other environmental aspects that are widely discussed regard the measure taken to reduce the air pollution in Beijing during the Games in 2008. At that time, Beijing was one of the most polluted city in the world, and the issue of air quality has been widely discussed prior to the Games, especially regarding whether the conditions would be safe enough for the athletes to compete outdoor. Short-term measures, only applied few days prior to the Games, but also during, were used to reduce the air pollution in the city. Those measures included for instance the limitation of the road traffic, the stopping of polluting industries in the city etc. Those measures Were not carried on afterwards, so no long-term positive impacts on the environment of the city was experienced regarding air quality.

Issue of temporality
Another issue that impede a good application of the concept of sustainability is the temporality of the Games. The Games have fixed deadlines which can be difficult to achieve, as only five years are given to the construction of new infrastructures, and this does not give any places to delays. Some sustainability commitments and environmentalism issues are forgotten when there is a need to complete all the construction in a limited times and at minimum costs. The problems met at the Olympic Village in Rio, where leaking pipes and electrical problems were found is an example. Additionally, with an increasing number of athletes and spectators and a worldwide broadcast, the Games have become a showcase to a global audience. This led to a tendency towards gigantism, which increases even more the difficulty to finish the work for the infrastructures on time.

Greenwashing?
Some of the Olympic Games organisers claimed to organise the most sustainable Games. This was the case for London (BBC, 2012). The fact that many sustainability commitments made prior to the Games are not fulfilled might suggest that there is some greenwashing within the Games' organisation. In fact, empty green policies, claims and unfulfilled promises are considered as greenwashing (Lyon and Montgomery, 2015).

A striking example could be that in the sustainability plan of Rio 2016, it was planned to plant 24 million of trees as a carbon offsetting solution. Yet, in the final post-Games report, it is indicated that only three million of trees were planted. This shows that many ambitious measures are promised in the sustainability plan, in order to show the public and other stakeholders, such as non-governmental organisation, that the Organisation is really committed to sustainability. Yet, in the end, the measures are not fulfilled or only partially. Additionally, knowing the situation in Brazil towards deforestation, this commitment appears as quite astonishing.

The concept of greenwashing relies on the misleading advertisement of corporations about the environmental performance of their products (Delmas and Burbano, 2011). This strategy has expanded over the last years, which has led to a greater scepticism of consumers and investors toward the authenticity of green claims (Lyon and Montgomery, 2015). The use of sustainability assessment tools, which increase transparency to the public seems to appear as a way to reduce the aspect of greenwashing in order to strengthen the legitimacy of the Games' organisers. This is especially the case with the ISO standard 20121, which aims at certifying that the organisation uses a sustainable management system, or with the green building certification. Yet, the ISO 20121 deals with the sustainable management system and the implementation of sustainable practices, but does not ensure that all the decisions taken are made with environmental awareness. For instance, London 2012 tried to integrate to incorporate the concept of sustainability in many different aspects of the Games, including the partners. British Petroleum and EDF, among all, were two of those "sustainable partners". Protestations and critics over this partnerships reduced the organisers' credibility over their ongoing discourse of making sustainable Games (Gaffney, 2013). This aspect also shows that the need for investment from sponsors, that are often international companies, prevails over environmental concerns.

8.2.2 Analytical and methodological limitation

Some limitations have arisen during the project. The research design chosen for this project was a multi-case studies. This type of design was interesting to use to have an overview of the practices regarding water sustainability at different Olympic Games, and see how those practices differ. Yet, the fact that several Games must be studied can make the assessment more superficial than if only one edition was studied. If only one Games have been studied, the design process of the Games, choices taken by the stakeholders regarding water sustainability, the limitations and actors involved could have been more deeply analysed. Besides, interviews could have been held with experts from those specific Games. This could have made the project a bit clearer, but the project would have only considered one specific strategy of one Games' organisers and this would have limited the identification of multiple strategies about the integration of water sustainability.

In addition, the limitation of the project relies on the comparison between Games. It is quite difficult to compare different Games who have different targets and different development plans, as well as local contexts extremely disparate. Those contexts make their comparison and sustainability assessment quite difficult, and it might have been interesting to have more similar cities, in terms of social, economic, political and environmental context in order to really be able to compare the measures and their effectiveness.

As mention in section 5.3.2, the reliability of the results can be questioned. Most of the data were retrieved from official reports from Organising Committees and other stakeholders of the Games. First, those reports represent the view of the Games' organisers, which can then transform the reality into their own perspective and thus hide some aspects. Additionally, the understanding of each report is based on a personal view which can be biased with existing knowledge or perceptions.

This problem of transparency and reliability with the reports is nonetheless counteracted with the analysis of reports from non-governmental organisations and press releases. Yet, it seems that those press releases mostly focus on the most important failures of the Games' organisers regarding their environmental commitments, and thus provide the reader a wrong perception of the situation. For instance, the water quality issue was widely discussed and reported in the media for Rio 2016, but nothing was written on the problem for the river Lea in London. This wider coverage seems to orientate the project towards the failure of the sustainability plan of Rio 2016, while all the commitments were not unfulfilled and apart from few athletes getting ill, most of them found the water quality safe enough (Blount, 2016).

This project was mostly based on the environmental practices and commitments of each Games' organisation towards water sustainability, but more details could have been given on the governance part - who is responsible for the decisions, who is responsible for their implementation etc. The financing part could have been more elaborated as well, in order to know the cost of the environmental measures compare to the overall costs of the Games, in order to really know the space given to the environment in the overall Games. Likewise, it could have been interesting to know the investments of each Games towards water sustainability. Yet, those data are not publicly available because too specific, and private.

Finally, this project only focused on the water sustainability as a window for the overall environmental sustainability, which then raise the issue of generalisation. If some recommendations and initiatives provided are quite general and can easily be generalised to the other sustainability dimensions, it is nonetheless essential to conduct more studies on the other sustainability dimensions as each have their own specificity and react differently with the Olympic Games. This project showed that the Games mostly have positive impacts on the water sustainability, but for some other dimensions it could be the contrary.

8.2.3   Different approaches

This project used one specific approach towards environmental sustainability and Olympic Games. The example of water sustainability was used to analyse if and how the Games can participate in the improvement of the urban environmental sustainability. A review of the main responses and their impacts was performed in order to provide Games' stakeholders possible initiatives in order to further enhance the water sustainability in their host city. Other approaches could have been considered to analyse the impacts of the Games on the urban environmental sustainability.

First, analysing more than one sustainability dimension could have provided a more relevant overview, as each dimension has its own challenges. Also, it could have been useful in order to see whether some of the patterns identified and recommendations provided for the water sector can be applied for another one, for instance, the waste or the energy. For instance, Beijing had really important water problems prior to the Games, and they put an important focus on it, so it seems that Beijing did a lot for the environment during the Games from a water perspective, but another trend might have been found if the focus of the project was on another dimensions.

Likewise, this project shows that Rio had some difficulties in achieving some of the targets regarding water sustainability, but for other sustainability dimensions another tendency might have been identified.

One direction that could have been considered would be to see how a sustainable assessment tool could be used for Olympic Games, and how the Games could benefit from the use of this tool. The Games' organiser already use green building certifications for some of their new infrastructures, but they do not use anything for existing and temporary buildings. An assessment tool for the sustainable design of the Games, used during the planning of the Games, with specific requirements regarding the environmental issues could be really valuable for the Games' organisers. This tool could include some of the recommended initiatives. Yet, as seen in the analysis, the impact of the Games are very wide, and it would be extremely complex to try and consider all the measures needed to tackled those impacts.

Another possible way to investigate the problem would have been to analyse other mega-events like the FIFA world cup, the panamerican or asian Games, or non-sport mega-event such as the World Fairs. Even though none of the other existing mega-events have as much impacts as the Olympic Games, it could have brought valuable insights with the identification of innovative practices. Similarly, some smaller events could have been taken into account, such as music festivals. Those events, being smaller in size than mega-event, have some interesting specificity that the Olympic Games could benefit from. Especially, a lot of small-scale events use temporary infrastructures, while it is a rather new practice at the Olympics. Studying how small-scale events tackle the environmental issues could then have offered interesting insights to be implemented by the Olympics.

An additional possibility could have been to dive more specifically into the legacy of the environmental responses of the Organising Committee. For instance, finding whether the knowledge gained during the planning of the Games regarding environmental sustainability has been integrated after the Olympic Games in the practices and overall learning of the local governments and companies involved in the delivery of the Olympic Games. This is an interesting subject which would need to be more studied, for instance with a single-case study on one specific edition, with interviews of different stakeholders. It would bring an even more specific answer to the question of whether hosting the Olympic Games really enhance the environmental sustainability in the city on the long-term.

8.3 Environmental Sustainability and Olympic Games

This last section discusses the relation between environmental sustainability and Olympic Games by first examining the enhancement of the use of sustainability tools for Olympic Games. Then, future perspectives on the relation between environmental sustainability and Olympic Games are provided.

8.3.1 Enhaning the use of sustainability assessment tools

The difficulty of quantitatively assess sustainability of Olympic Games

At the beginning of the project, it was considered to quantitatively assess the environmental sustainability of Olympic Games. Yet, different challenges were identified. First, the finding of quantitative data was difficult, and second the finding of common and quantitative data, measured in the same way, for the different Games was almost impossible. It was not achievable to go for the first idea of this project which was to quantitatively assess the environmental impacts of the Olympic Games.

Most of the papers found in the literature on the sustainability assessment of the Olympic Games have a qualitative approach, and even though sometimes the assessment is based on indicators, the score of those are based on the expert's judgement of qualitative data (Pitts and Liao, 2013). After this project and the difficulty of accessing specific quantitative data, it makes sense why the authors in the academic literature mostly take qualitative approach as no quantitative data are made available by the Games' organisers.

Also, it explains why some studies only deal with the discussion on whether an existing tool, such as the ecological footprint, can be useful for the Olympic Games and not specifically apply the tool, due to the lack of quantitative data. Only the Olympic Games Impact Study, the carbon footprint and the green building certification are based on quantitative data. Those tools are used by the Games' organisers who have access to those specific quantitative data because they are the ones generating those data. In order to build new and innovative sustainability assessment tools, a wider opening of quantitative data of different Games' editions on a specific platforms that could be accessible to anyone could really improve the discussion on quantitative assessment of the impacts of the Olympic Games. This would really help scientifics and other major interested parties to really involved in the overall improvement of the existing tools, or the creation of new assessment tools. This platforms would also provide a greater transparency.

The analysis of the existing tools used for the Olympic Games showed they do not provide enough outputs for decision-making. Thus, one could argue that to better influence decision-making, there is a need to manage sustainability in a better way. From the observations made just previously, one can wonder whether the use of sustainability tools is the right solution to enhance the sustainability of Olympic Games. Thus, it appears that tools are not sufficient to effectively change the story.

Ways of improvement

From the description and discussion of each tool in chapter 6, it seems that even though the tools have methodological limitations and do not ensure the staging of sustainable Olympic Games, the use of those tools have nonetheless enhanced the sustainability of Olympic Games. Sustainability tools are thus essential and their use should be promoted. One reason which could explain the lack of total efficiency of the sustainability tools are their recent character. Indeed, for most of them, they have been applied for the first time in London in 2012. Thus, for the moment, the tools have only been used twice for Summer Olympic Games: in London and Rio, and this might not be enough to get constructive feedbacks for improvement and implement those. Thus, a continual improvement for those tools should be conducted by the IOC and the other Olympic' stakeholders.

Using sustainability assessment is a learning process. One problem for the difficulty of the Games' organisers towards the use of the tools can be that they use the tool only once for the Games that they organise. Then, it can be difficult for them to really understand the methodology behind and to know how to apply it. Some specific departments within the Olympic Committee are responsible for the application of the tools, and for each new Games, those departments need to get the overall understanding of the tools. One possible perspective is that it could be the same group of person working with the tools for each Olympic Games, a group which would be part of each Organising Committee. This way, one can argue that it would increase the knowledge on the use of the tools.

As well, it could ensure that those tools are well applied and that the benefits from their usage are enhanced through the learning process from one edition to another. This group of persons could be a group of independent experts working in collaboration with each Organising Committees, and could act as an external and critical viewer on the measures taken by the Organising Committees.

From the analysis and observations made during this project, one specific type of tool that could be very valuable for the Olympic Games has emerged. This tool would be used during the planning of the Games - during the bid and two years after the winning of the bid - and should be designed like a sustainability certification tool like BREEAM, LEED or DGNB. This tool would not tackle only one building or one neighbourhood but would integrate all the different infrastructures of the Games, the new ones as well as the existing ones. The overall goal of the tool would be to guide the planners of the Games towards the best choices based on the available knowledge, obtained through the involvement of all the important stakeholders. It could increase the transparency towards the choice of a specific design, because it could give a clear message on the different possible alternatives. By including the existing strategic development plans of the city, and involving environmental, economic, social and legacy aspects, this tool could be a way to enhance the overall sustainability of the Olympic Games. Nonetheless, designing the Games is highly complex, so much more research should be performed on whether such a tool could really bring more value.

8.3.2 Future perspectives for sustainability and Olympic Games

This section presents some of the future perspectives on sustainability and Olympic Games. It first deals with the inclusion of other pillars within the planning and management of Olympic Games. Then, it discusses the future perspectives towards the integration of environmental sustainability in the Olympics.

Economic, social and legacy aspects

In this project, only one pillar of the concept of sustainability was considered. Yet, this concept also includes the social and economic pillars. Thus, in order to have an holistic overview of the relation between the sustainability and Olympic Games, the three pillars should have been considered, because one cannot say whether a Games is sustainable only based on the environmental pillar.

Additionally, sustainability tools try to provide better information in order to guide the decision making but in practice there are many other external factors influencing the decision making. For the Olympic Games, first the technical requirements from the International Olympic Committee and to some extent the economic costs prevails over the environmental commitments.

The relation between Olympic Games and the economic pillar is widely reviewed in the literature. It appears that it is still a great challenge for Games' organisers to respect the initial costs of the Games. This can be due to an underestimation of the costs of future project, a tendency which is observed for planners (Flyvbjerg, 2007). This is especially seen for the Olympic Games, because during the bid process, there is a trend to estimate the costs downwards in order to be competitive with the other candidate cities. Then during the preparation of the Games, the costs always rises. One reason is that as the delivery of the infrastructures can not be delayed, the costs rise in order to finish the infrastructures on time. The facts that the real costs are always higher than the planned costs and that not all the entire city benefits from those investments really question whether the Olympic Games can be economically sustainable.

Equally, the concept of legacy should not be overlooked. Indeed, this project mostly focused on the environmental state during the Games, and did not look forward. Yet, in order to fully capture the environmental impacts of a project, the overall life-cycle of the Games should have been considered. This would have needed more information on the situation after the Games, how the new infrastructures are maintained and used. For London, this would have been very easy as a special company to manage the legacy of the Games was created. For Beijing and Rio, the management of the legacy is much more difficult, as the abandoned infrastructures in their Olympic Parks suggest. This is again related to a tendency that the planners overestimate their ability towards an effective delivery of the legacy outcomes (Flyvbjerg, 2007).

For instance, the Olympic Park in Rio was closed for safety reasons at the beginning of 2020. Even though some of the venues reopened after two or three years of disuse, the lack of maintenance in the venues as well as in the paths of the park has led to a deterioration of the materials and infrastructures, which is now considered too dangerous (BBC, 2020). One can thus wonder the necessity of the implementation of environmental measures in the Olympic Park if this park is not used after the Games, because the environmental impacts of this disuse would be extremely high from a life-cycle perspective. Therefore, it can be argued that before focusing on the environmental sustainability of the new infrastructures, there is a need to really work on the legacy aspects. This also highlights the reasons why existing infrastructures should be preferred over new ones.

Evolution of Environmental sustainability within the Olympic Movement

The last Games' editions were increasingly used to raise awareness of the local population as well as the athletes over environmental challenges. Tokyo developed recyclable beds made in cardboard for the Olympic Village. Old electronic devices from Japanese were used to make the Olympic medals. Those two example surely do not have important positive environmental impacts but they are good ways to raise awareness towards waste recycling by making the inhabitants participate in the preparation for the Games. Also, those measures are often widely presented and discussed in the media worldwide so that it reaches many people around the world. Those two examples show that public participation can be used in the implementation of the environmental responses to raise the overall awareness, and this has not been observed for any Games yet.

If the sustainability tools used are not sufficient, another possibility to raise the sustainability of the Olympic Games is the change of the overall framework of the Games. In 2018, the IOC changed the mandatory requirements, in order to reduce the costs and size of the Games. It is not presented as a way to tackle the ineffectiveness of sustainability assessment tools that Games' organisers were using. Rather, this new norm was released in order to reduce the constraining measures. This document is called The New Norm, and introduces more flexibility and less requirements for the host country. One of the main changes is that there is no more requirements that all the competition venues must be located within the region of the host city. It means that some competitions can be held in another city in the region, or in another country. This is especially recommended for competition that need the construction of new venue, but where the demand for this specific sport in the host country is very low. One example could be the Olympic Venues for canoeing or kayaking, that are often built especially for the Games but are left abandoned after, due to the very low public demand to use it, like in Athens 2004, Beijing 2008 and Rio 2016 (Ravasi, 2018).

Another challenge addressed in this norm to reduce the footprint of the Games is to maximise the use of venues. In fact, competitions of different sports could be held in the same venue, but due to the tight timeframe of the Games, only two weeks, several venues are needed to host the competitions of those sports (Long, 2013). The IOC proposes to promote the sharing of venues through more optimized calendars. This would reduce the need for building new infrastructure, and thus reduce the gigantism of the Games.

This new norm highlights a strategic change within the International Olympic Committee, which still has not set mandatory sustainability requirements, but increases the flexibility for the design and choice of venues for the Olympic Games. Those propositions are quite innovative, but they have not been applied yet. The first time those propositions will be considered will be for the Winter Games in 2026 in Milano. It is still unknown how the host cities will consider those new requirements, if they will be applied, and if the future Organising Committee will actually address the issue of reducing the size and costs of the Games, and overall have a lower environmental impacts on the host city.

Therefore, many efforts are still required towards sustainable Olympic Games, in order to move beyond greenwashing, and to integrate the concept of sustainability in a meaningful and transparent way within the Olympic movement.

9 Conclusion

Taking departure in the negative impacts of mega-events and the difficulty of implementing a new sustainability model within the Olympics', this project studied the relation between urban environmental sustainability and Olympic Games.

To integrate sustainability within the Olympic, different sustainability tools are used by the Games' organisers. Yet, the use of those tools do not ensure the sustainability of the Games. In fact, despite their disparate but complementary approaches, they have many limitations that impede their effectiveness. Overall, none of those tools provide sector-specific guidelines in order to positively influence the decision-making during the planning of the Games.

In order to bridge this gap, a multi-case study was performed on the latest editions of Olympic Games to understand the dynamics of the responses towards the integration of environmental sustainability within the organisation of the Olympic Games. The case of water sustainability was used to act as an example of how the environmental sustainability can be enhanced with the hosting of Olympic Games. For water quality, the main responses rely on the building of new wastewater treatment plants in order to decrease the pressure on water bodies appeared to be efficient. For water availability, the use of state-of-the-art technologies for water saving and reuse in the new infrastructures are the most common measures taken by the Games' organisers. Different initiatives were provided, aiming at decreasing the environmental impacts of the Games through the enhancement of sustainable practices. Those initiatives are addressed to different Games' stakeholders - the IOC and the Games' organisers - and include the use of state-of-the-art technologies and a better governance within the Games' organisation, and the setting of more ambitious and constraining sustainability requirements by the IOC to the OCOG.

Related to the water sustainability, the Olympic Games play a positive role through the development of new water-related infrastructures such as wastewater treatment plants. Besides, the Olympic Games provide a framework in which the existing development plans are enhanced, like the water management plans. Finally, the Olympic Games act as an opportunity to implement new sustainability initiatives and innovative technologies during the Games, as well as afterwards with the learning of new environmental practices in the host city. Those roles can be generalized to some extent for some of the other sustainability dimensions, such as waste, energy or transport. This way, it can be said that the Olympic Games can enhance the environmental sustainability of the city.

Yet, the integration of the environmental sustainability within the Olympics has limitations. The prevalence of economic aspects and technical requirements over environmental considerations, the overestimation of the capacities during the planning and choice of sustainability commitments, but also the mismanagement during the preparation of the Games still generate negative environmental impacts. The Games then play a negative role in the host city regarding environmental sustainability. Those challenges question whether the integration of environmental sustainability is just a discourse or really positively influences the urban environment. Therefore, in order to move beyond green-washing and integrate sustainability in the Olympic movement in a meaningful and transparent way, efforts from the different stakeholders of the movement must be continued.

Bibliography

Abebe, N., Bolton, M. T., Pavelka, M., and Pierstorff, M. (2014). *Urban Development and the Olympics*, pages 7–13. Springer New York.

Ali, M. F. and Sarah, W. (2015). The Queen Elizabeth Olympic Park water recycling system, London. In *Alternative Water Supply Systems*. IWA Publishing.

Ana, A. (2015). Rio's Olympic village: a green housing dream, but a gentrification nightmare – video. Retrieved from https://www.theguardian.com/sustainable-business/video/2015/aug/19/rio-olympics-ilha-pura-luxury-development-leed, Last visited: 19-05-2020.

Azzali, S. (2018). Mega sporting events as tools of urban redevelopment: lessons learned from Rio de Janeiro. *Proceedings of the Institution of Civil Engineers - Urban Design and Planning*, 172:1–26.

Bakos, A. R. (2019). The institutionalisation of sustainability in event management: A case study of the diffusion of ISO 20121 at the Gold Coast 2018 Commonwealth Games.

Bauer, A. (2017). Rio Olympic village begins retrofit. *Around the rings,*. Retrieved from http://aroundtherings.com/site/A__59524/Title__Rio-Olympic-Village-Begins-Retrofit/292/Articles, Last visited: 19-05-2020.

Baum, G. and Cherny, D. (2016). Rio Olympics 2016: Athletes' village 'unliveable', Kitty Chiller reveals 'stress test' failure. Retrieved from https://www.smh.com.au/sport/rio-olympics-2016-athletes-village-unliveable-20160724-gqcqxy.html, Last visited: 19-05-2020.

BBC (2012). London 2012 'most sustainable' Olympics, watchdog says. Retrieved from https://www.bbc.com/news/uk-england-london-20334658, Last visited: 19-05-2020.

BBC (2020). Rio Olympic Park: Judge orders closure of site over safety concerns. Retrieved from https://www.bbc.com/news/world-latin-america-51133312, Last visited: 19-05-2020.

Beijing 2008 (2009). Bid documents and analysis: Passion behind the bid. Available at https://stillmed.olympic.org/Documents/Reports/Official%20Past%20Games%20Reports/Summer/ENG/2008-RO-S-Beijing-vol1.pdf, Last visited: 18-05-2020.

Bidone, E. and Lacerda, L. (2004). The use of DPSIR framework to evaluate sustainability in coastal areas. case study: Guanabara Bay basin, Rio de Janeiro, Brazil. *Regional Environmental Change*, 4(1):5–16.

Blaikie, N. and Priest, J. (2019). *Designing social research: The logic of anticipation*. John Wiley & Sons.

Blount, J. (2016). Sailing: Athletes fed up with Rio water-quality complaints. *Reuters*. Retrieved from https://www.reuters.com/article/us-olympics-rio-sailing-water-idUSKCN10K237, Last visited: 18-05-2020.

Boggia, A., Massei, G., Paolotti, L., Rocchi, L., and Schiavi, F. (2018). A model for measuring the environmental sustainability of events. *Journal of environmental management*, 206:836–845.

Boroghi, F., Ribeiro, P., and Lourenço, J. M. (2018). Olympics' impacts in Rio de Janeiro's urban sustainability. Available at http://repositorium.sdum.uminho.pt/bitstream/1822/56051/1/2864-TR.30-011677.7759.7765.pdf, Last visited: 11-05-2020.

Bradley, P. and Yee, S. (2015). *Using the DPSIR framework to develop a conceptual model: technical support document*. US Environmental Protection Agency, Office of Research and Development.

Bryman, A. (2016). *Social research methods*. Oxford university press.

Cantelon, H. and Letters, M. (2000). The making of the IOC environmental policy as the third dimension of the Olympic movement. *International review for the sociology of sport*, 35(3):294–308.

Carr, E. R., Wingard, P. M., Yorty, S. C., Thompson, M. C., Jensen, N. K., and Roberson, J. (2007). Applying DPSIR to sustainable development. *International journal of sustainable development & world ecology*, 14(6):543–555.

Chen, Y., Qu, L., and Spaans, M. (2013). Framing the long-term impact of mega-event strategies on the development of Olympic host cities. *Planning Practice & Research*, 28(3):340–359.

Chestney, N. (2012). London Olympics' emissions 28 percent lower than forecast: organiz-

ers. *Reuters*. Retrieved from https://www.reuters.com/article/us-olympics-emissions/london-olympics-emissions-28-percent-lower-than-forecast-organizers-idUSBRE8BB0C320121212, Last visited: 19-05-2020.

Ciegis, R., Ramanauskiene, J., and Startiene, G. (2009). Theoretical reasoning of the use of indicators and indices for sustainable development assessment. *Engineering Economics*, 3.

Collins, A. and Flynn, A. (2008). Measuring the environmental sustainability of a major sporting event: A case study of the FA Cup Final. *Tourism Economics*, 14(4):751–768.

Davis, J. (2019). Avoiding white elephants? The planning and design of London's 2012 Olympic and Paralympic venues, 2002–2018. *Planning Perspectives*, pages 1–22.

De La Cruz, A. R. H., Calderon, E. R. D., França, B. B., Réquia, W. J., and Gioda, A. (2019). Evaluation of the impact of the Rio 2016 Olympic Games on air quality in the city of rio de janeiro, brazil. *Atmospheric environment*, 203:206–215.

Delaplace, M. and Schut, P.-O. (2019). *Hosting the Olympic Games: Uncertainty, Debates and Controversy*. Routledge.

Delmas, M. A. and Burbano, V. C. (2011). The drivers of greenwashing. *California management review*, 54(1):64–87.

Dolf, M. M. (2017). *A life cycle assessment of the environmental impacts of small to medium sports events*. PhD thesis, University of British Columbia.

Dominiczak, P. (2012). London 2012: More than 2m fans visit London for Games. *The Independant*. Retrieved from https://www.independent.co.uk/sport/olympics/news/london-2012-more-than-2m-fans-visit-london-for-games-7987307.html, Last visited: 04-05-2020.

Douglas, L. (2011). Zero-waste Olympic Games [waste management]. *Engineering & Technology*, 6(12):46–47.

Dupont, V., Jordhus-Lier, D., Sutherland, C., and Braathen, E. (2015). *The politics of slums in the global south: urban informality in Brazil, India, South Africa and Peru*. Routledge.

Eduardo Suarez, L. (2016). After the party: Rio wakes up to an Olympic hangover. *The Guardian*. Retrieved from https://www.theguardian.com/books/2016/aug/21/rio-2016-olympic-games-brazil-legacy-party, Last visited: 18-05-2020.

EEA (1999). Environmental indicators: Typology and overview. Retrieved from https://www.eea.europa.eu/publications/TEC25, Last visited: 19-05-2020.

Espeland, W. N. and Stevens, M. L. (2008). A sociology of quantification. *European Journal of Sociology/Archives Européennes de Sociologie*, 49(3):401–436.

Essex, S. and Chalkley, B. (1998). Olympic Games: catalyst of urban change. *Leisure studies*, 17(3):187–206.

Essex, S. and Chalkley, B. (1999). Urban development through hosting international events: a history of the Olympic Games. *Planning perspectives*, 14(4):369–394.

Faria, F. (2016). How Green Building Council Brasil shaped the sustainability of the Rio 2016 Olympic venues. *World Green Building Council*. Retrieved from https://www.worldgbc.org/news-media/how-green-building-council-brasil-shaped-sustainability-rio-2016-olympic-venues, Last visited: 19-05-2020.

Fioravanti, G. (2008). Environmental indicators and their use for indicator-based reporting activities. Agency for Environmental Protection and Technical Services.

Flyvbjerg, B. (2007). Policy and planning for large-infrastructure projects: problems, causes, cures. *Environment and Planning B: planning and design*, 34(4):578–597.

Furrer, P. (2002). Sustainable Olympic Games. *Bollettino della Società Geografica Italiana*, (4).

Gaffney, C. (2010). Mega-events and socio-spatial dynamics in Rio de Janeiro, 1919-2016. *Journal of Latin American Geography*, pages 7–29.

Gaffney, C. (2013). Between discourse and reality: The un-sustainability of mega-event planning. *Sustainability*, 5(9):3926–3940.

Garcia-Ramon, M. and Albet, A. (2000). Pre-Olympic and post-Olympic Barcelona, a 'model' for urban regeneration today? *Environment and Planning A*, 32:1331–1334.

Geeraert, A. and Gauthier, R. (2018). Out-of-control Olympics: Why the IOC is unable to ensure an environmentally sustainable olympic games. *Journal of Environmental Policy & Planning*, 20(1):16–30.

Getz, D. and Page, S. J. (2016). *Event studies: Theory, research and policy for planned events*. Routledge.

Gold, J. R. and Gold, M. M. (2013). "Bring it under the legacy umbrella": Olympic host cities and the changing fortunes of the sustainability agenda. *Sustainability*, 5(8):3526–3542.

Gordon, B. F. (1983). *Olympic architecture: building for the Summer Games*. John Wiley & Sons.

Gratton, C. and Preuss, H. (2008). Maximizing Olympic impacts by building up legacies. *The international journal of the history of sport*, 25(14):1922–1938.

Greenpeace (2008). China after the Olympics. Available at https://www.greenpeace.org/usa/wp-content/uploads/legacy/Global/usa/report/2008/8/china-after-the-olympics.pdf, Last visited: 19-05-2020.

Guthoff, I. (2016). Creating a sustainable olympic games. *Syracuse J. Int'l L. & Com.*, 44:357.

Hensher, D. A. and Brewer, A. M. (2002). Going for gold at the Sydney Olympics: how did transport perform? *Transport Reviews*, 22(4):381–399.

IOC (1999). Olympic's movement agenda 21 - Sport for sustainable development. Available at https://stillmed.olympic.org/media/Document%20Library/OlympicOrg/Documents/Olympism-in-Action/Environment/Olympic-Movement-s-Agenda-21.pdf, Last visited: 04-05-2020.

IOC (2006). Olympic Games Global Impact. *Olympic Review*. Retrieved from https://stillmed.olympic.org/Documents/Reports/EN/en_report_1077.pdf, Last visited: 19-05-2020.

IOC (2007). Technical Manual on Olympic Games Impact. Available at http://www.gamesmonitor.org.uk/files/Technical_Manual_on_Olympic_Games_Impact_June_2007_FINAL.pdf, Last visited: 19-05-2020.

IOC (2017a). IF sustainability case study - water quality working group. Available at https://stillmed.olympic.org/media/Document%20Library/OlympicOrg/IOC/What-We-Do/celebrate-olympic-games/Sustainability/Case-Studies/2017/IF%20SCS-WATER%20QUALITY.pdf, Last visited: 19-05-2020.

IOC (2017b). IOC sustainability strategy. Available at http://extrassets.olympic.org/sustainability-strategy/#_ga=2.244510405.1383597341.1590479150-1194188154.1578415365 , Last visited: 19-05-2020.

IOC (2018). Carbon footprint methodology for the Olympic Games. Available at https://stillmed.olympic.org/media/Document%20Library/OlympicOrg/IOC/What-We-Do/celebrate-olympic-games/Sustainability/IOC-Carbon-Footprint-Methodology.pdf, Last visited 11-05-2020.

ISO (2012). Sustainable events with ISO 20121. Available at https://www.iso.org/files/live/sites/isoorg/files/store/en/PUB100302.pdf, Last visited 11-05-2020.

Jackson, R. and Bonard, C. (2011). Delivering London 2012: environmental management. *Proceedings of the Institution of Civil Engineers*, 164(5):20–26.

Kassens-Noor, E. (2013). Transport legacy of the Olympic Games, 1992–2012. *Journal of Urban Affairs*, 35(4):393–416.

Kassens-Noor, E. (2019). "Failure to adjust": Boston's bid for the 2024 Olympics and the difficulties of learning Olympic wisdom. *Environment and Planning A: Economy and Space*, 51(8):1684–1702.

Kitchen, T. (1996). Cities and the 'world events' process. *Town and Country Planning*, 65(11):314–317.

Konstantaki, M. (2018). Environmental sustainability of Olympic Games: a narrative review of events, initiatives, impact and hidden aspects. *Journal on Tourism Sustainability*, pages 48–68.

Krieger, J. and Langenbach, B. (2018). Emergence of the environment policy of the International Olympic Committee: A historical analysis. *Journal of Qualitative Research in Sports Studies*, 11:15–32.

Kristensen, P. (2004). The DPSIR framework. *National Environmental Research Institute, Denmark*, 10.

Lalande, N., Cernesson, F., Decherf, A., and Tournoud, M.-G. (2014). Implementing the DPSIR framework to link water quality of rivers to land use: methodological issues and preliminary field test. *International journal of river basin management*, 12(3):201–217.

Lauermann, J. (2014). *Legacy after the bid? The impact of bidding to host the Olympic Games on urban*

development planning. Lausanne: Olympic Studies Centre.

Leopkey, B. and Parent, M. M. (2012). Olympic Games legacy: From general benefits to sustainable long-term legacy. *The international journal of the history of sport*, 29(6):924–943.

Lewison, R. L., Rudd, M. A., Al-Hayek, W., Baldwin, C., Beger, M., Lieske, S. N., Jones, C., Satumanatpan, S., Junchompoo, C., and Hines, E. (2016). How the DPSIR framework can be used for structuring problems and facilitating empirical research in coastal systems. *Environmental Science & Policy*, 56:110–119.

Liao, H. and Pitts, A. (2006). A brief historical review of Olympic urbanization. *The International Journal of the History of Sport*, 23(7):1232–1252.

LOCOG (2005). London 2012 Olympic Games official report. Available at https://library.olympic.org/Default/doc/SYRACUSE/37734/london-2012-olympic-games-the-official-report-the-london-organising-committee-of-the-olympic-games-a?_lg=fr-FR, Last visited 19-05-2020.

LOCOG (2007). Towards a one planet 2012. Available at http://data.parliament.uk/DepositedPapers/Files/DEP2007-0171/DEP2007-0171.pdf, Last visited 19-05-2020.

LOCOG (2010). Carbon footprint study. Available at https://static1.squarespace.com/static/577ccaf4414fb56605df7a9a/t/58eba9aa1e5b6c098ba70f19/1491839856782/carbon+footprint+study+london+2012, Last visited 11-05-2020.

LOCOG (2011). Learning legacy - lessons learned from the London 2012 Games construction project. Available at https://www.designcouncil.org.uk/sites/default/files/asset/document/London%202012%20Original.pdf, Last visited 19-05-2020.

LOCOG (2012). The official commemorative book. Available at https://stillmed.olympic.org/Documents/Reports/Official%20Past%20Games%20Reports/Summer/ENG/2012-RO-S-London_V2.pdf, Last visited 19-05-2020.

London Assembly (2012). Water matters - efficient water management in London. Available at https://www.london.gov.uk/sites/default/files/gla_migrate_files_destination/Water%20management%20report%20pdf.pdf, Last visited 19-05-2020.

Long, J. (2013). Rethinking Olympic infrastructure. Retrieved from https://urbanage.lsecities.net/essays/rethinking-olympic-infrastructure, Last visited: 13-05-2020.

Lyon, T. P. and Montgomery, A. W. (2015). The means and end of greenwash. *Organization & Environment*, 28(2):223–249.

Maloutas, T., Sayas, J., and Souliotis, N. (2009). Intended and unintended consequences of the 2004 Olympic Games on the sociospatial structure of Athens. In *ISA-RC21 Sao Paulo conference. Inequality, inclusion and the sense of belonging*, pages 23–25.

Moldan, B., Janoušková, S., and Hák, T. (2012). How to understand and measure environmental sustainability: Indicators and targets. *Ecological Indicators*, 17:4–13.

Müller, M. (2015). (im-) Mobile policies: Why sustainability went wrong in the 2014 Olympics in Sochi. *European Urban and Regional Studies*, 22(2):191–209.

Nations, U. (2001). *Indicators of sustainable development*. United Nations. Available at https://www.un.org/esa/sustdev/csd/csd9_indi_bp3.pdf, Last visited: 14-05-2020.

Niiler, E. (2016). The mad dash to clean up Rio's Guanabara Bay before the Games. *Wired*. Retrieved from https://www.wired.com/2016/07/mad-dash-clean-rios-guanabara-bay/, Last visited: 18-05-2020.

Nolen, S. (2016). Dirty Water. *The Globe and Mail*. Retrieved from https://www.theglobeandmail.com/news/world/dirty-water-why-rio-hasnt-kept-its-promise-to-cleanup/article30752991/, Last visited: 18-05-2020.

OECD (1991). Environmental indicators, a preliminary set.

OECD (1993). OECD core set of indicators for environmental performance reviews. *Environmental Directorate Monographs No.83*.

OECD (2003). OECD Environmental Indicators: Development, measurement and use. Available at url http://www.oecd.org/environment/indicators-modelling-outlooks/24993546.pdf, Last visited 14-05-2020.

Paquette, J., Stevens, J., and Mallen, C. (2011). The interpretation of environmental sustainability by the

International Olympic Committee and Organizing Committees of the Olympic Games from 1994 to 2008. *Sport in Society*, 14(03):355–369.

Parent, M. M., MacDonald, D., and Goulet, G. (2014). The theory and practice of knowledge management and transfer: The case of the Olympic Games. *Sport management review*, 17(2):205–218.

Parkes, O., Lettieri, P., and Bogle, I. D. L. (2015). Life cycle assessment of integrated waste management systems for alternative legacy scenarios of the London Olympic Park. *Waste management*, 40:157–166.

Parkes, O., Lettieri, P., and Bogle, I. D. L. (2016). Defining a quantitative framework for evaluation and optimisation of the environmental impacts of mega-event projects. *Journal of environmental management*, 167:236–245.

Patroncini, D. (2013). Water quality investigations of the river Lea. Available at https://core.ac.uk/download/pdf/29821706.pdf, Last visited 14-05-2020.

Petersson, B. and Vamling, K. (2016). Vanished in the haze: White elephants, environmental degradation and circassian marginalization in Post-Olympics Sochi. In *Mega Events in Post-Soviet Eurasia*, pages 59–76. Springer.

Pitts, A. and Liao, H. (2013). An assessment technique for the evaluation and promotion of sustainable Olympic design and urban development. *Building Research & Information*, 41(6):722–734.

Poynter, G., Viehoff, V., and Li, Y. (2015). *The London Olympics and urban development: The mega-event city*. Routledge.

Probe International (2008). Beijing's water crisis; 1949 — 2008 Olympics. Available at http://www.chinaheritagequarterly.org/016/_docs/BeijingWaterCrisis1949-2008.pdf, Last visited: 19-05-2020.

Qiu, Y., Tiwari, A., and Wang, Y. D. (2015). The diffusion of voluntary green building certification: a spatial approach. *Energy Efficiency*, 8(3):449–471.

Rapport, D. (1979). Towards a comprehensive framework for environmental statistics: a stress-response approach. *Statistics Canada 11-510, Ottawa, 1979*.

Ravasi, A. (2018). Une partie des sites des Jeux Olympiques de Pékin laissés à l'abandon. Retrieved from https://www.lefigaro.fr/le-scan-sport/2018/08/11/27001-20180811ARTFIG00054-une-partie-des-sites-des-jeux-olympiques-de-pekin-laisses-a-l-abandon.php, Last visited: 19-05-2020.

Rijina, T. and Sujith, K. (2019). Role of mega-events in urban development. In *Recent Advances in Materials, Mechanics and Management: Proceedings of the 3rd International Conference on Materials, Mechanics and Management (IMMM 2017), July 13-15, 2017, Trivandrum, Kerala, India*, page 354. CRC Press.

Rio 2016 (2013). Sustainability Management Plan: Rio 2016 Olympic and Paralympic Games. Available at http://www.climateaction.org/images/uploads/documents/sustainability_management_plan_aug2013.pdf, Last visited: 04-05-2020.

Rio 2016 (2014). Embracing change: Rio 2016 sustainability report. Available at https://library.olympic.org/Default/doc/SYRACUSE/73418/embracing-change-rio-2016-sustainability-report-organising-committee-for-the-olympic-and-paralympic-?_lg=en-GB, Last visited: 04-05-2020.

Rio 2016 (2016a). Post-Games sustainability report Rio 2016. Available at https://library.olympic.org/Default/doc/SYRACUSE/184692/post-games-sustainability-report-rio-2016-organising-committee-for-the-olympic-and-paralympic-games-, Last visited: 18-05-2020.

Rio 2016 (2016b). Rio 2016 carbon footprint report. Available at https://quantis-intl.com/wp-content/uploads/2017/02/rio-2016-carbon-jul2016-ing.pdf, Last visited 11-05-2020.

Ross, W. J. and Leopkey, B. (2017). The adoption and evolution of environmental practices in the Olympic Games. *Managing sport and leisure*, 22(1):1–18.

Rowberg, K. and Rincker, M. (2019). Environmental sustainability at the Olympic Games: Comparing Rio 2016 and Tokyo 2020 Games. *European Journal of Sustainable Development*, 8(4):121–121.

Salcines, J. L. P., Babiak, K., and Walters, G. (2013). *Routledge handbook of sport and corporate social responsibility*. Routledge.

Samuel, S. and Stubbs, W. (2013). Green Olympics, green legacies? an exploration of the environmental

legacies of the Olympic Games. *International Review for the Sociology of Sport*, 48(4):485–504.

Sananhuja, R. (2002). Barcelona–an Olympic city–the city strategy 10 years after the Olympic Games in 1992. In *The International Conference on "Sporting events & Economic Impact", April. Copenhagen, Denmark*.

Sánchez, E., Colmenarejo, M. F., Vicente, J., Rubio, A., García, M. G., Travieso, L., and Borja, R. (2007). Use of the water quality index and dissolved oxygen deficit as simple indicators of watersheds pollution. *Ecological indicators*, 7(2):315–328.

Sánchez, F. and Broudehoux, A.-M. (2013). Mega-events and urban regeneration in Rio de Janeiro: planning in a state of emergency. *International Journal of Urban Sustainable Development*, 5(2):132–153.

Schmedes, S. (2015). *Sustainable design of sports stadiums: case study analysis of stadiums for the Olympic Games 2000 in Sydney, 2004 in Athens and 2008 in Beijing*. PhD thesis, Cardiff University.

Schwambach, K. F. (2012). Mega-events in Rio de Janeiro and their influence on the city planning. In *Proceedings of the 15th International Planning History Society Conference, São Paulo, Brazil*, pages 15–18.

Searle, G. (2012). The long-term urban impacts of the Sydney Olympic Games. *Australian Planner*, 49(3):195–202.

Smith, A. (2014). Using temporary venues to stage the Games: Lessons from London 2012. Available at http://digital.la84.org/digital/api/collection/p17103coll10/id/13752/download, Last visite: 14-05-2020.

Spangenberg, J. H. (2002). Institutional sustainability indicators: an analysis of the institutions in Agenda 21 and a draft set of indicators for monitoring their effectivity. *Sustainable Development*, 10(2):103–115.

Stewart, A. (2012). Olympic Host Cities need transparency, not knowledge transfer. *Harvard Business Review*. Retrieved from https://hbr.org/2012/08/olympic-host-cities-need-trans, Last visited: 11-05-2020.

Sun, S., Wang, Y., Liu, J., Cai, H., Wu, P., Geng, Q., and Xu, L. (2016). Sustainability assessment of regional water resources under the DPSIR framework. *Journal of Hydrology*, 532:140–148.

The Guardian (2015). Athletes at Rio Olympics to compete in 'basically raw sewage', study reveals. Retrieved from https://www.theguardian.com/sport/2015/jul/30/athletes-at-rio-olympics-to-compete-in-basically-raw-sewage-study-reveals, Last visited: 18-05-2020.

The New York Times (2008). To save Olympic sailing races, China fights algae. Retrieved from https://www.nytimes.com/2008/07/01/world/asia/01algae.html, Last visited: 19-05-2020.

The Telegraph (2016). Rio's dirty water claims 'first victim': star Belgian sailor sick after racing on polluted bay. Retrieved from https://www.telegraph.co.uk/olympics/2016/08/11/rios-dirty-water-claims-first-victim-star-belgian-sailor-sick-af/, Last visited: 04-05-2020.

Theodoraki, E. et al. (2016). The problem with sporting mega-event impact assessment. *Global Corruption Report: Sport*, pages 169–177.

Toniolo, S., Mazzi, A., Fedele, A., Aguiari, F., and Scipioni, A. (2017). Life cycle assessment to support the quantification of the environmental impacts of an event. *Environmental Impact Assessment Review*, 63:12–22.

Trendafilova, S., Graham, J., and Bemiller, J. (2017). Sustainability and the Olympics: The case of the 2016 Rio Summer Games. *Journal of Sustainability Education*, 16.

Tziralis, G., Tolis, A., Tatsiopoulos, I., and Aravossis, K. (2008). Sustainability and the Olympics: The case of Athens 2004. *International Journal of Sustainable Development and Planning*, 3(2):132–146.

UEL (2013). Olympic Games Impacts Study - London 2012 Games-time report. Retrieved from https://www.uel.ac.uk/research/centre-for-geoinformation-studies/researchareasprojects/ogisgamestimelondon2012, Last visited: 19-05-2020.

UNEP (2009). Independant Environmental Assessment. Available at https://www.uncclearn.org/sites/default/files/inventory/unep36.pdf, Last visited: 19-05-2020.

UNESCO (2019). World water development report 2019 - leaving no one behind. Available at https://en.unesco.org/themes/water-security/wwap/wwdr/2019, Last visited: 19-05-2020.

UNESCO and IANAS (2015). Urban water challenges in the Americas. Available at https://unesdoc.unesco.

org/ark:/48223/pf0000246414, Last visited: 19-05-2020.

United Nations (2016). Transforming our world: The 2030 agenda for sustainable development. Available at https://sustainabledevelopment.un.org/post2015/transformingourworld, Last visited: 19-05-2020.

United Nations (2018). 2018 revision of world urbanization prospects. Available at https://population.un.org/wup/Publications/Files/WUP2018-Report.pdf, Last visited: 19-05-2020.

Vanwynsberghe, R. (2015). The Olympic Games Impact (OGI) study for the 2010 Winter Olympic Games: Strategies for evaluating sport mega-events' contribution to sustainability. *International Journal of Sport Policy and Politics*, 7(1):1–18.

Venetsanou, P., Voudouris, K., Kazakis, N., Mattas, C., et al. (2015). Impacts of urbanization, agriculture and touristic development on groundwater resources in the eastern part of Thermaikos Gulf (North Greece): an application of DPSIR model for sustainable development. *European Water*, 51:3–13.

Waas, T., Hugé, J., Block, T., Wright, T., Benitez-Capistros, F., and Verbruggen, A. (2014). Sustainability Assessment and Indicators: Tools in a decision-making strategy for sustainable development. 6:5512–5534.

Wang, S., Zhao, M., Xing, J., Wu, Y., Zhou, Y., Lei, Y., He, K., Fu, L., and Hao, J. (2010). Quantifying the air pollutants emission reduction during the 2008 Olympic Games in Beijing. *Environmental science & technology*, 44(7):2490–2496.

Watts, J. and Vidal, J. (2016). What's in the water? Pollution fears taint Rio's picturesque bay ahead of Olympics. *The Guardian*. Retrieved from https://www.theguardian.com/sport/2016/aug/03/pollution-fears-taint-rio-bay-olympic-games, Last visited: 18-05-2020.

Weiler, J. and Mohan, A. (2010). The Olympic Games and the triple bottom line of sustainability: opportunities and challenges.

World Commission on Environment and Development (1987). Our common future. Available at https://sustainabledevelopment.un.org/content/documents/5987our-common-future.pdf, Last visited: 19-05-2020.

Yin, R. K. (2011). *Applications of case study research*. SAGE.

Yin, R. K. (2017). *Case study research and applications: Design and methods*. SAGE.

Zhou, Y., Ap, J., and Bauer, T. (2012). Government motivations for hosting the Beijing 2008 Olympic Games. *Journal of Tourism and Cultural Change*, 10(2):185–201.

Zhou, Y., Wu, Y., Yang, L., Fu, L., He, K., Wang, S., Hao, J., Chen, J., and Li, C. (2010). The impact of transportation control measures on emission reductions during the 2008 Olympic Games in Beijing, China. *Atmospheric Environment*, 44(3):285–293.