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# Sustainable Wave as a Legacy to London from the 2012 Olympics

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**Abstract**
The Olympic Games are an intercultural huge event that usually leaves the city with megaprojects and related huge debts for their constructions after the Games. However London and environment conscious Londoners started the Olympic bid with the intention to leave a legacy to the city and thus earned the right to host the 2012 Olympics. Their Olympic proposal had sustainability in the forefront, prominently featuring the rehabilitation of a former industrial zone in the east side of the city. The Aquatic Centre is one the buildings that lie at the heart of the aforementioned olympic park. Its architect, Zaha Hadid, designed its main form inspired by a wave that is able to transform, meaning while the Aquatic Centre was designed to have the necessary 17,500 seating capacity for the Olympics, later it would transform into 2,500 seats for public everyday use. The aim of this paper is to examine and learn from the outlook of the Aquatic Centre to its environment, raw materials, natural resources and workforce involvement during its life cycle. In this context, the phases of its inception, construction period, shining in the Olympics and eventually becoming a part of the community as a legacy are examined according to sustainability so that learning from the story of this iconic sports building would be possible. The identification and implementation of performance improving strategies in this project points to many areas, in which the stakeholders can work together in various phases of the building to bring sustainable construction knowhow to the future generations.
**Keywords:** Sustainability, Stakeholder, Innovative materials, Aquatic centre, Transformation

## 1. Introduction

The terms Olympics and sustainability are usually controversial since Olympics, even including Paralympics, do not last more than six weeks and leave the host city with lots of structures that will not reach full capacity again in addition to causing a lot of construction debt (Dwyer et al., 2005; Searle, 2002). In its bid for the 2012 games, London had a different strategy with focus on "greenest as ever Olympics" (Hayes and Horne, 2011). It had a plan that would re-green and regenerate the East London boroughs. The chosen site was an old rail yard and engine depot and Europe's most toxic brownfield site with a series of canals (Lowenstein, 2012). For the Olympics the terrain would need rehabilitation and an entire ecosystem would be redeveloped. In addition, three of the boroughs of the site were among the six poorest in the country, and the promised legacy with low energy infrastructure, a sports park, new housing and work areas would be just a beginning.

In 2005 London won the Olympic bid and the organizing body, the London Olympic Delivery Authority (ODA) and The London Organising Committee of the Olympic Games and Paralympic Games Ltd. (LOCOG) began their work. They introduced the framework for the London 2012 sustainability programme with the publications London 2012 Sustainability Policy in July 2006 and the London 2012 Sustainability Plan in November 2007, wherein they introduced many principles including low energy buildings, zero carbon, zero waste, sustainable transport and sustainable food as objectives. Yet the ODA did not tell how to reach these objectives and the contactors had to search for ways and share these ways among themselves to reach these objectives.

While the target was to finish the work in time for the Olympics, actually the work was done for the legacy. The Olympic Park would become the Queen Elizabeth Olympic Park after the Games as a gift for London and mainly East London. Nearly all the venues of the park were designed for disassembly. While there were many temporary structures, the permanent structures were designed to have downsized capacities after the games for use of the general public. The housing would be converted to mixed housing and many work and retail areas would be available (Evans, 2015). This paper focuses on the story of one of the permanent buildings, the Aquatic Centre, which is the most technically challenging building in the Olympic Park. Positioned on the south eastern edge of the Olympic Park "Figure 1" shows the Aquatic Centre as a centerpiece that lies on the road from the rail station and the Athlete's housing.

## 2. Architectural Concept

The Aquatic Centre was designed by Zaha Hadid during the preparation for the Olympic bid. It is an iconic structure that was the result of a 2004 design competition. The facility would house 3 pools, one of which is the

50 m olympic pool, one is the 25 m diving pool, and one is the 50 m training pool. Its narrow site with a canal on one side and rail tracks on the other side nearly determines the layout of the Aquatic Centre. The pools would only be placed parallel to the canal, therefore the spectators'' seating would be placed the perpendicularly. Adjacent to the Centre is a 45 m footbridge, from which the majority of the spectators would enter the Olympic park. The training pool is placed under this pedestrian bridge thus 10% of the roof area would be decreased.
The Centre has a complex geometry and design. The conceptual competition design was optimized for the site that allowed for around 50% decrease in the carbon footprint, yet it still as the largest footprint amongst the permanent venues. Other site constraints include being a very environmentally contaminated site, requiring extensive remediation and 235,000 tonnes of total loose aggregates, over 80 per cent of which were from a recycled source, were necessary. Also underground power lines that carry electricity to east London run under the site and to not load the power lines, an extensive network of piles was utilized. In addition only 4 m deep groundwater exerting upward pressure on the pools led to a heavy weight design thus decreasing carbon in the materials became paramount.

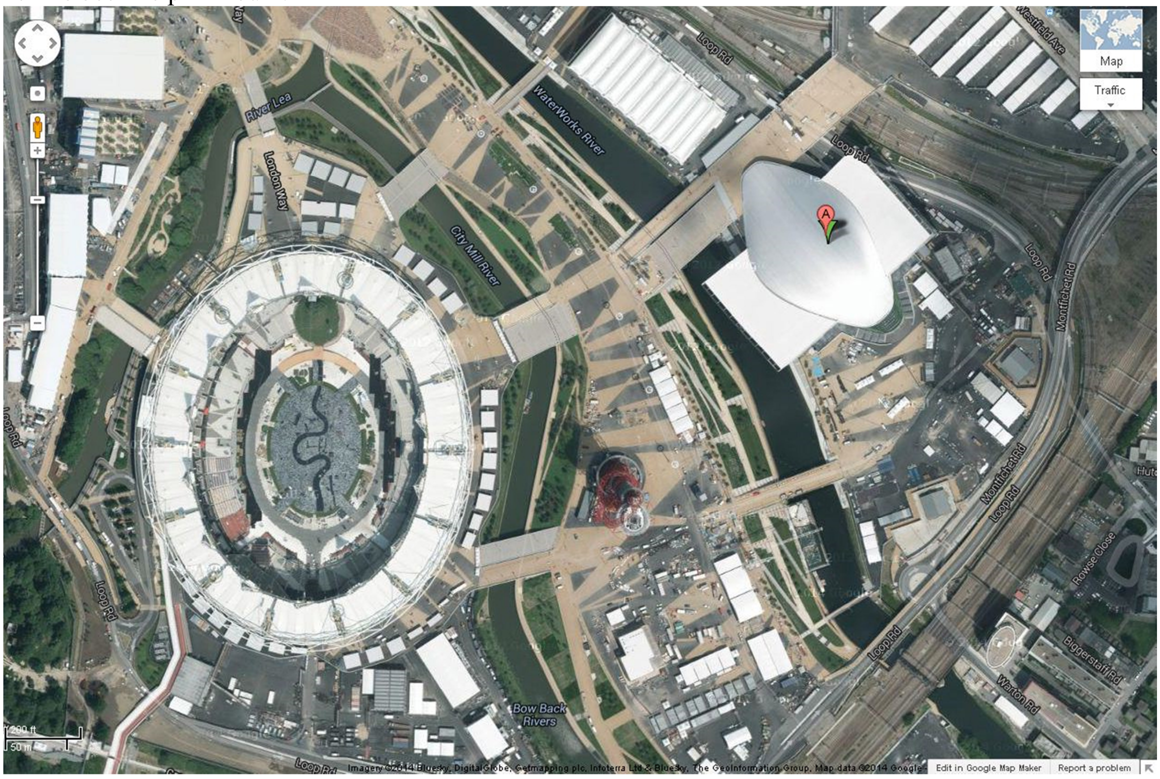

Figure 1. The site of the Aquatic Centre (http://maps.google.com, Imagery ©2014 Bluesky).

The most eye-catching element, the 3,200 tonne steel roof is responsible for 13% of the building's carbon footprint. Since a column free space is desired, over 100 m span was necessary for the permanent roof and each member operates at a 90% capacity. Concrete walls support the wavelike roof from 3 points. Its hyperbolic paraboloid geometry is shown in "Figure 2", and divides the interior space into 2, for the swimming and diving events. The roof geometry also creates optimum viewing conditions for the spectators while forming a saddle, with higher viewing areas and a lower ceiling at the top of the pool.


Figure 2. Panaromic of the London Olympic Park
http://commons.wikimedia.org/wiki/File:London_Olympic_Park_from_John_Lewis.jpg) Creative Commons Attribution-Share Alike 3.0 Unported license.

## 3. Construction Phase

The construction program was such that the construction needed to start before many of ODA's assessment framework was put in place. The contractor and construction team was one of the first on site and needed to create many sustainable solutions. It later shared many of its innovative solutions with other contractors. One of the most important solutions was to translate sustainability objectives into detailed design brief and design guides. The client was informed in all areas of project delivery with inspections, submitted data and audits. The design team and the contractor worked together on site. The delivery partner provided technical support and assurance for the project's duration. The client and the project team had a supportive and completely transparent relationship and held regular workshops and progress meetings. Also the regulatory authorities were involved with many environmental challenges regarding the site during the construction process "Figure 3".

Figure 3. During the construction process (http://commons.wikimedia.org/wiki/File:London_Aquatics_Centre,_10_December_2009.jpg) Creative Commons Attribution-Share Alike 2.0 Generic license.

A work package was the main tool developed to translate broad level objectives into specific requirements. The objectives were featured in the tender process for contractors as clear contract requirements and the results of each work package were logged therefore ownership and accountability for any action would be possible. This process was also embedded into the procurement process of the contractor therefore the procurement and supply chain management. Bringing over 55% of key building materials by sustainable transport decreased vehicle movements on local roads. These materials include aggregates, precast concrete and pool tiles by rail delivery directly to the venue. The rail delivery was a core requirement of the tender. The rail operator also provided storage for programme critical goods. Deliveries from the river were also tried but were not successful (Henson, 2012).

Concrete is a local material, ensuring traceable and highly regulated supply chains thus there is a growing concern in the industry for using concrete sustainably (Horvath, 2004). In this project, first, 11% of the concrete volume was decreased by efficient design solutions leading to 20.000 tonnes of embodied CO2 and 120.000 tonnes of primary aggregate savings. The contractor in some cases used coarse aggregate substitution from stent, glass sands and recycled concrete aggregate and reached 169.000 tonnes of primary aggregate substitution. They did trials to establish the maximum ground granulated blast-furnace slag (GGBS), a waste by-product from the steel industry, for cement substitution and were rewarded a BREEAM innovation credit for their contribution to sustainable concrete construction. As a result, they used 40% GGBS mixture for the high fair finish visible concrete in the venue such as the diving boards. They also used 55% and 70% GGBS substitution in substructure elements (Whitehead, 2012; Henson, 2011). Moreover, the contractor shared their experiences with other contractors.

Another significant challange of the contractor's supply chain was insufficient quantities of sustainable timber to meet the Aquatics Centre's demand of 485 m3 of the preference for Red Louro, a graffiti resistant Brazilian hardwood, for the timber ceiling. Alternative timbers were not appropriate either technically or architecturally. The solution was an internal Red Louro veneer on birch plywood with solid Red Louro external cladding that enabled the use of 50% less Red Louro, all sourced from a credible supplier. In addition, the laminate solution 40 tonnes of secondary steel for the ceiling was replaced with fully prefabricated structural timbers that led to minimal wastage (Henson, 2012).

Waste was sorted on-site, in a dedicated area within the site boundary. To encourage the workforce to segregate their waste, other facilities were provided closer to the operatives. This waste management scheme led to 64% site segregation, additionally approximately 96% of waste was diverted from landfill. Moreover reusable materials such as timber and wooden pallets were stored. They were later transformed to planters for local schools, donated to an urban farm or sold by a local company. They increased the visibility and awareness of the construction in the local community. Also field trips to and from local schools were encouraged to increase awareness.

In addition to the construction process, social considerations were also a major aspect. All the contractors offered apprenticeships and recruited from the local area. They both created jobs and developed skills of the local people (Norman, 2013). In addition diversity training was provided to the workforce by their senior managers. In the "Respect for People" program, both the workers and the trainers were trained. Moreover, after the trainings were over, volunteers continued the spirit of the trainings with workshops and other activities (Morley, 2011). Another thing worth noticing is the encouragement of providers to build on existing sustainable practices for also food. All the catering staff received training and sought to maximise energy and water efficiency and minimise emissions.

**4. Olympic Mode**

The flexibility of the seating capacity was considered after the bid was won therefore two temporary stands for 15,000 were added for the Games. "Figure 4" shows the Olympic Mode of the venue. The temporary stands were made from bolted steelwork so that they would be dismantled and reused at the end of their Olympic life. The 19,000m2 roof and walls were finished with a fabric wrap. In response to the ODA's poly-vinyl chloride (PVC) policy, an innovative, flexible and phthalate-free poly-vinyl chloride was installed.

Figure 4. The Olympic Mode (http://commons.wikimedia.org/wiki/File:London_Aquatics_Centre_panorama.jpg) Creative Commons Attribution 2.0 Generic license.

Rather than conditioning the entire pool hall the systems for the Olympic mode focused on providing a comfortable environment at the pool and for spectators thus mechanical cooling was entirely eliminated due to the natural ventilation in the temporary stands. Detailed thermal modelling and elemental redesign of the 15,000 seat temporary structures resulted in approximately 56 tonnes of carbon saving during Games-time operation. To eliminate hydrofluorocarbons (HFCs) from permanent cooling systems ammonia chillers were preferred. This substitution indicates a benefit of 130 tonnes equivalent CO2 in the 25-year life-cycle global warming of the venue. Carbon footprint was further reduced by drawing space and hot water heating from the Park-wide district heating network (Henson, 2012).

In addition the building was well insulated. The pool and substructure were constructed with insulated concrete with a u-value of 0.25W/m2K, walls insulated with a u-value of 0.20W/m2K. Also the air tightness of the building was improved to 5m3/m2h, which is half the baseline value. In addition the efficiency of mechanical and electrical systems were improved. Natural daylight sensitive dimmable pool lights, heat recovery in ventilation systems and the displacement ventilation system to minimise pool water evaporation are the main saving points (Carris & Knight, 2011). As a result, the designed Building Emission Rate for the Aquatics Centre was estimated to be 15.3 per cent better than the Target Emission Rate compared to a benchmark building.

**5. Legacy Mode**

After the games the entrance bridge to the Park was reduced to 14 m and the temporary stands were removed (Figure 5). The openings left from the stands were finished with a 14 m high cantilevered glazed curtain wall, which floods the interior with natural daylight. Although the legacy capacity was reduced to 2,500 the volume of the venue still represents significant challenge for in use energy efficiency yet the roof geometry was optimized for passive solar heating in winter and solar shading to prevent summer overheating. A water based façade heating system was integrated into the façade mullions. The wall is highly efficient, with u-value of 1.4W/m2K (Henson, 2012).

Figure 5. The Legacy Mode (http://commons.wikimedia.org/wiki/File:London_Aquatics_Centre.jpg) Creative Commons Attribution-Share Alike 2.0 Generic license.

Another significant resource buildings consume during their life cycle is water. The Aquatic Centre would demand the most freshwater (over 23%) on the Olympic Park's 25 year lifecycle. This is not only because of the pools but also because the users would often shower before entering and after leaving the pool. 924Ml out of total 1,384Ml water demand was calculated for showering purposes. 29% of the water demand would be reduced through water efficiency by using efficient fittings (low flow showers, taps and WCs) and pool management, namely covering the pools and raising the floors when the pools were not in use. A further 3% water demand would be reduced by the utilization of a third of the swimming pool backwash water to flush WCs and urinals. This would reduce the 25 year lifespan baseline water usage from almost 450Ml (Carris & Knight, 2012). Furthermore a small rainwater harvesting system was installed for the use of green roof and the chiller compound.

**6. Conclusion**

London 2012 was the first summer Games to measure and capture its carbon footprint. The result for the Olympic Games is impressive and some of ODA's targets were surpassed. 400,000 tonnes of CO2 equivalent against reference carbon footprint was decreased, 99% of a total of 61,000 tonnes of waste from installing and decommissioning Games venues were reused or recycled, 62% out of a total of 10,173 tonnes of Games operational waste was actually reused, recycled or composted, 86% of Olympic Park visitors travelled by rail, 39% of staff directly employed by LOCOG at the peak of the Games had been unemployed prior to their recruitment, and 23.5% of staff directly employed by LOCOG during the Games were resident in one of the six Host Boroughs (LOCOG, 2012a).

While many consider the Velodrome as the epitome of sustainable design in the Olympic Park, the Aquatic Centre with its clear vision supported by defined objectives and measurable targets has also made significant contributions to the sustainability agenda. Early planning and design intent is usually the way to achieve sustainability, yet this project had a rocky start in these areas. Since its architectural design was in place before the sustainability criteria of the client was fully formed the targets had to be reached by employing small incremental changes at late stages in the design process. Although the venue was built over 269 million pounds, about 3 times the estimated price, such a technically challenging building could still respond to many challenges and make significant sustainability improvements.

The overall performance of the Aquatic Centre is given in "Table 1". Although it is criticized as being less sustainable than it could be because of iconic and prestige concerns nonetheless The Aquatic Centre is a success story since it has reached and even surpassed many of its targets even though the Aquatic Centre had a difficult site with a complex brief. Overall, the application of many processes showed a refreshing view of sustainability. Processes such as comprehensive design guidance, defined regular monitoring and reporting requirements, a value-based tender process, and replication through the supply chain and the use of work packages simplified the sustainability agenda and made it accessible to all, thus ownership of work became possible (LOCOG, 2012b). Therefore other projects of the Olympic park and the past Olympic venues will be researched in future studies. In addition, other megaprojects generating events such as the Expos will be studied.

Table1. Overall performance of the Aquatic Centre

| Environment & Sustainability Indicators | ODA Target | Project achievement |
|---|---|---|
| 1.Energy in Use<br>Energy Efficiency (better than Part L) | <br>15% | <br>15.3% |
| 2. Water<br>Potable Water Reduction | <br>30% | <br>32% |
| 3. Waste<br>Reused or recycled (construction) | <br>90% | <br>95% |
| 4. Materials<br>Timber from legal & sustainable sources<br>Key materials responsibly sourced<br>Recycled content by value<br><br>Recycled aggregate by weight<br>Healthy materials (low VOC / water based)<br>BRE Green Guide rating | <br>100%<br>80%<br>20%<br><br>25%<br>80%<br>A+ to C | <br>100%<br>85%<br>28.9% Aquatics<br>33% Bridge F10<br>51%<br>100%<br>A+ to D |
| 5. Biodiversity<br>Area of new habitat<br><br>Bird and Bat Boxes | <br>2185m2 (Legacy Mode)<br>23 bird boxes<br>11 bat boxes | <br>484 m2 (Olympic Mode)<br>1701m2 (Legacy Mode)<br>23 bird boxes<br>11 bat boxes |
| 6. BREEAM<br>BREEAM (Permanent Venues) | <br>Very Good - 65.05% | <br>Excellent - 73.67% |
| 7. Environmental Impacts<br>CEEQUAL<br>Considerate Constructors Scheme<br><br>Sustainable Transport (Deliver 50% by Rail/Water)<br>Compliance with Code of Construction Practice | <br>Very Good<br>Score of 4 in each section<br>50%<br><br>Yes | <br>Excellent - 94.5%<br>Score of 4 in each section<br>56%<br><br>Yes |

Although processes alone cannot deliver sustainability, a comprehensive understanding of the sustainability agenda across the whole project team was created and preserved by the repetition of the processes. In addition, the team was given the motivation and opportunities to innovate. Besides its contribution to its surroundings, the real legacy of the Games will be its impact on the construction industry regarding responsibility for a low carbon future.

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