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GSOE9820 Engineering Project Management

Project 3 – ARUP: Building the Water Cube

Project Report - Group 28

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Executive Summary

One of the iconic buildings from the 2008 Beijing Olympics is the Beijing National Aquatic Center, also known as the Water Cube. A collaboration between Arup, PTW Architects and the Chinese Construction Design Institute, the building was a commercial, design and project management success. This report summarises the discussions of Group 28 about various aspects of this project.

This document is the final report of Project 3, in which we study the design of the Water Cube. In the following sections, we analyse various elements of the project and how high-quality work can be generated. Sections 2 & 3 explore the innovations and accomplishments of the project. We rank the challenges faced during the project in Chapter 4. In Chapters 5, 6 & 7, we analyse the practices that lead to the project's success, how Arup encourages high-quality work in general and what lessons are learned from the project.

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1. Introduction

When Beijing was selected as the host city for the 2008 Olympics, various new venues were designed. One of the best-known is the Water Cube (officially the Beijing National Aquatics Center) designed by a consortium of Arup, PTW Architects and the Chinese Construction Design Institute. It features striking design elements, innovative technology and excellent project management.

During the whole project, the project management team encountered various challenges in many aspects such as culture cooperation, team management and budget & time constraints, through appropriate management, some hi-tech tools and some innovative ideas, the team finally completed the goal to deliver such an appealing building. We analyse these specific issues to explore how the team successfully complete the high-quality project and get some experiences and lessons.

2. Innovations in the Water Cube

2.1. Analysis:

In this question, we were asked to determine the innovations that were used or developed during the design of the water cube. We took innovations to be new ideas, tools or techniques that were applied to this project. We assumed that innovations could occur in any sector (i.e. not just technological).

2.2. Key Innovations:

Our key innovations in the project were split into two categories:

1. Technological Innovations:
   a. Ethylene Tetrafluoroethylene (ETFE): The use of ETFE was an innovative choice as it had not been widely adopted. ETFE was chosen as its physical characters could allow up to 30% more light and heat to enter the cube, reducing the energy usage to reach the goal of environmental sustainability. It could also resist UV radiation and solar pollution and have significantly light weight (Wilson, 2009). By using such an innovative material, the sustainability objective was hugely improved.
   b. Innovative use of Building Information Modelling: During the project, BIM software was relatively new. BIM and Arup's expertise in IT and scripting were used by the team to solve some problems (Zou & Leslie-Carter, 2010). The design team innovatively used BIM not only to share data efficiently and worked from different locations but also to create 3D models in low amount of time and easily visualize these designs.
2. Concept Innovations:
   a. Interface Management: Arup team introduced an innovative strategy to manage the projects interfaces. By defining different types of interfaces between different design sections, the team could coordinate all parts of the design team and successfully deliver an Olympic Venue (Zou & Leslie-Carter, 2010).
   b. Sustainable design: A fundamental goal of designing this venue was sustainable both in environmental and social and economic aspects (Eccles et al. 2010, pg. 1). Sustainability was carried through the whole design. While sustainability was not a major consideration in most projects at the time, the post-Beijing Olympics' adoption of this concept by other designs shows the innovation of this idea.
   c. Design: Structures such as Weaire-Phelan foam (Fig. 1) structure were combined with aspects of traditional Chinese culture to produce one of the Beijing Olympics most striking structures. Flat concepts were included in this building to symbolize peace and stability in Chinese traditional cultures, contrasting with the chaotic nature of the Bird's Nest (Eccles et al. 2010, pg. 5). Besides, the bubbles provided reinforcement to the load-bearing structure of the Water Cube, one of the first membrane-based buildings in the world (Water Cube, n.d.).

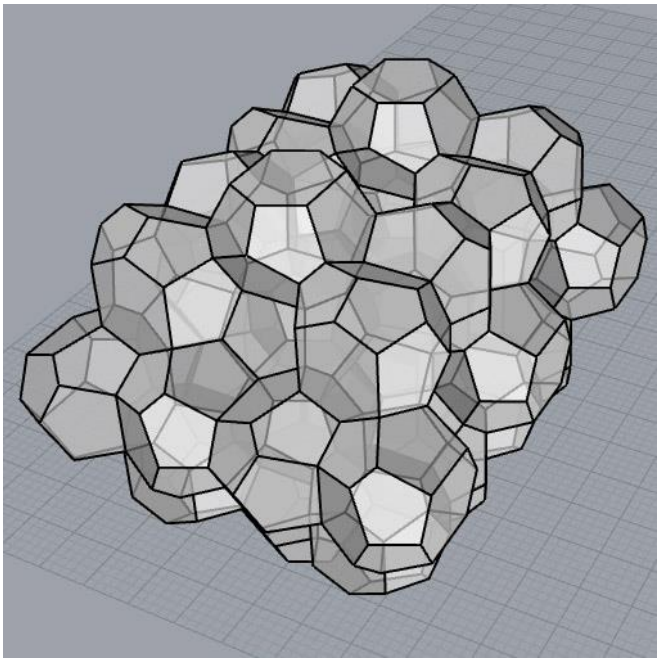

Figure 1: Visualisation of the Weaire-Phelan foam structure (Design Coding 2013)

3. Major Accomplishments of the Water Cube Project

3.1. Analysis:

From the case study and other materials, we were asked to extract the main accomplishments, which we took to be things that were done successfully, during the Water Cube project. We assumed that this was not limited to any stage of the design process, but across the entire project.

3.2. Accomplishments:

The main points of accomplishment that we found are listed below:

1. Sustainability's promotion: As the immense success of the sustainable design of this project, sustainability was considered by many projects as part of the design going forward (Eccles et al. 2010), and it also impacted Beijing's people to consume energy more efficiently.
2. Multi-culture collaboration: As the design was co-shared between 4 companies with various cultural backgrounds, a huge achievement was the collaboration that occurred between various companies. Their varying backgrounds were effectively utilized to make better designs than any group could have made individually. Although the design had been fast-paced and risky, it was in the end successful and the success of this collaboration initiated a change of how foreign companies operated with local Chinese businesses, moving to a partner structure (Eccles et al. 2010).
3. Quality vs. Cost: By the innovative design approaches, this project produced a high-quality, innovative and appealing building with a budgeted cost, which was a big achievement in the building industry (Eccles et al. 2010).
4. Meeting deadlines: In such a large project, it was a challenging task to meet all deadlines without sacrificing the quality of the design or profits, but this project accomplished this challenge (Eccles et al. 2010).
5. Fire certification: The Water Cube was the first Olympic venue to receive fire certification, setting a trend for the Olympic buildings that followed (Eccles et al. 2010).

6. In recognition of the phenomenal work that was done, the team was awarded 18 awards for various aspects of the design of the Water Cube (Eccles et al. 2010).

4. Major Challenges of designing and building the Water Cube

4.1. Analysis:

For this task, we listed and ranked all challenges experienced during the design and construction of the Water Cube, where we took a challenge to be anything that could lead project to fail. The scale of ranking was from 1 to 10, as prescribed in the guidance issued. As we were not privy to the day-to-day challenges faced by the team, these were not included in the list of challenges.

4.2. Challenges:

The challenges identified are listed below, in order of their difficulty. The scale of the challenge was identified by each team member individually and the average mark was taken. Some scores were adjusted under consideration of the points made.

1. Cultural Differences (9): Cultural differences proved to be one of the largest challenges that the team had to face, threatening the direction of this project at the beginning. Disagreement between PTW Architects and the China Construction Design Institute towards the choices of building structure were present at the project start (Eccles et al. 2010, pg. 5). Whilst this difference was resolved when the proposal was entered, cultural differences still existed in the project and different working styles, (e.g. Chinese companies rely heavily on personal relationships), must be coordinated (Zou & Leslie-Carter, 2010). There were also large differences between Arup's and Beijing business culture which lacked regulatory transparency.
2. Team Management (8): More than 100 staff distributed in 4 locations (Australia, UK, China and Hong Kong) formed the design team (Zou & Leslie-Carter, 2010). Managing such a large team of diverse professionals is a challenging problem. When groups are not adequately informed of others work, they may produce designs which are not compatible with the overall design. Besides, the geographical separation could exasperate the issue due to time differences. Besides, the design team contained various specialists that opposed strict supervision and they would directly resist leadership moves, especially from those less technically qualified (Eccles et al. 2010, pg. 11), which brought extra team management challenges. The issues faced by the project management team were not only varied but also persisted throughout the entire project.
3. Convincing the Chinese officials of fire safety (7): Due to the unconventional structure and the innovative use of ETFE, the design team had to convince Chinese authorities that their design was safe (Eccles et al. 2010, pg. 9). Whilst ETFE had previously been used in designs such as the Eden Project (Eccles et al. 2010, pg. 4), reducing the research effort that had to be undertaken, it was still a critical challenge for the team.
4. Large Scope/Requirements (7): A large number of requirements had to be met to make this a fully functional Olympic venue. Besides, strict requirements were given about enabling the transition of the Water Cube from an Olympic Venue to a publicly usable pool (Eccles et al. 2010, pg. 3).
5. Changing project requirements (6): During the design process, the requirements of the project changed two times, both reducing the building size (Eccles et al. 2010, pg. 4, 8). Due to the computer-based nature of the design, this challenge was masterfully handled by the design team, despite the number of changes that had to be made for such changes.

6. Non-involvement of Arup in Construction (6): During the construction process, the design team had no involvement, which created a burden to produce all the required design documentation to construct the Water Cube. In fact, some members of the Arup project management team travelled there unofficially but were denied entry to the construction site (Zou & Leslie-Carter, 2010). If the documentation process was not done thoroughly, the construction phase of the project could have suffered significant set-backs and the deadlines could have been missed.
7. Budget and Time Constraints (6): As the 2008 Beijing Olympics were scheduled for a specific date, the time for this project was constrained. Besides, the budget was tightly specified to be $100 million for the construction and $10 million for the retrofit after the Olympics (Eccles et al. 2010, pg. 3). Completing a project of this scope and complexity with such constraints was a challenge for the design team.
8. Technological Challenges (4): Various design challenges had to be overcome, such as the creation of computer models for the entire design, structural optimisation of all the designs trusses and the rapid prototyping (Eccles et al. 2010). Whilst such challenges are often faced by design engineers, they were challenges nonetheless, especially due to their innovative nature.
9. Multiple Stake Holders (3): Various stakeholders had a claim to the project, resulting in a number of different demands and parties that had to be kept informed. Especially due to Arup's belief in providing high-quality updates (Eccles et al. 2010, pg. 12), it was a challenge to keep all stakeholders satisfied and informed.

5. Practices and Processes that enabled the success

5.1. Analysis:

In this question, the team analysed what steps or policies Arup had taken or put in place in order to ensure that the project was carried out successfully. This was often linked to a particular challenge found in the previous section. As the report didn't discuss the construction of the Water Cube in detail, those processes were not considered in this question.

5.2. Practices and Processes:

We identified and analysed the following practices:

1. Detailed communication strategy: By defining a clear strategy for communication, both within the team and to the stakeholders, the team was able to quickly and effectively communicate changes to everyone. It played an important role in the communications with stakeholders, to ensure they were kept up to date and pleased with the result. An example of a communication structure was to produce high-quality communication and have this presented by well-respected engineers (Eccles et al. 2010, pg. 10, 12).
2. Project Management Team: As more than 100 people worked on the project, having a dedicated project management team allowed teams to work independently but yet still to a common goal (Eccles et al. 2010, pg. 11). Additionally, the work was spread into 4 streams, which allowed work to be done in parallel and by project managers with technical skills in those areas, allowing the project to advance far more quickly (Eccles et al. 2010, pg. 12).
3. SPeAR: Using the Sustainable Project Appraisal Routine allowed Arup to quickly and clearly identify how sustainable the current design was and produce recommendations

for improvement (Eccles et al. 2010, pg. 10, 12). This played a huge role in creating a high-quality, sustainable design.

4. Interface Management: The team applied some tools to enable them to handle different aspects of the projects and coordinate requirements. They build their interface system on some previous work of Arup; allowing them to manage the interfaces of all the different systems throughout the entire design process (Eccles et al. 2010, pg. 11).
5. Involvement of all cultures: By collaborating with different cultures, it created a symbiotic relationship, allowing the final product to be better than could be created by just any one culture.
6. Total Design: Involving all disciplines of the design from the beginning reduced conflicts later in the design as all teams could describe their needs and proposals early. Additionally, it allowed innovative applications to all facets of the design, due to technical specialists being involved early, when innovative ideas could be easily applied (Eccles et al. 2010, pg. 10).
7. Choice of building materials: The team made innovative choices in selecting the building materials, such as the choice of ETFE. By applying new materials in this design, they ensured the Water Cube was at the cutting edge of technology.
8. Implementation Plan: The team made a plan that informed all team members of the plan and vision of the building. This enabled all team members to work effectively on the project and reduce redundant work (Zou & Leslie-Carter, 2010).
9. Use of Technical Expertise: A huge amount of technical expertise was applied to this project. The team's efficient use of BIM to model the building both in 3D and 4D helped them plan the building completely virtually and allowed them to respond to changes quickly, such as the reduction in size (Eccles et al. 2010, pg. 8). They also applied tools such as computer-based structural optimization to reduce the weights and cost of all the structures. (Eccles et al. 2010, pg. 8).

6. Approaches adopted by Arup to produce high-quality projects

6.1. Analysis:

Here, we extended the analysis from Section 5 to include general Arup company policies that allowed their staff to create brilliant designs. For this, we specifically looked beyond specific practices, but more towards the methodology and ethos that Arup applies to all its projects, not just the water cube.

6.2. Approaches:

The approaches and methods that Arup uses to encourage high-quality work are found below:

1. Company culture: Arup has a culture of having talented creative employees to do interesting projects (Arup, n.d.). Arup gives its employees the freedom to try out different ideas, allowing individuals from all walks of life to collaborate and come up with the best ideas together. This attracts employees that strive to generate such projects for themselves. Besides, Arup is operated in a trust for the employees (Eccles et al. 2010), increasing the attachment and pride that people take in their work.
2. Cross-Cultural Relations: The encouragement of maintaining cross-cultural relations and learning from these leads to a better exchange of ideas and learning of the experience of others. An example with the water cube is the collaboration between CCDI and PTW (Eccles et al. 2010, pg. 12), where the cultural experience of CCDI formed the basis of the winning design.

3. Conflict Management: By recognizing and confronting the fact that conflicts happen within projects and project teams, Arup could ensure that the projects can proceed as without major issues. If conflicts were left undealt with, it could easily lead to larger conflicts within the team. This had the potential to happen during the early stages of the design of the Water Cube when the team from PTW and CCDI disagreed about the design (Eccles et al. 2010, pg. 4). By solving this conflict in a way that kept all parties happy, Arup was able to ensure that the design would continue as cohesively as possible.
4. Management Model/Experience: By applying Arup's project management, they allow staff to work more efficiently and innovatively. The staff critical to the project are all experienced, giving more freedom for a design team to go about its work (Eccles et al. 2010, pg. 11).
5. Milestone celebration: Arup ensures that its employees are kept up to date with event and feel the accomplishment of having completed tasks. Such events could include milestone celebrations or briefings (Zou & Leslie-Carter, 2010).
6. Total Design Approach: By including all members of a project team from the beginning, it helps connecting the technically brilliant members of their team with other employees, further increasing the quality of their work.

7. Lessons learned by Arup from this project

7.1. Analysis:

Lastly, the team analysed what lessons could be learned by Arup from this project; which could be applied in later projects. We attempted to go beyond just having a particular experience, and rather focus on the tools, methods and ideas that can be applied to future projects.

7.2. Lessons Learned:

1. Learning from different cultures: The design that was selected in the end was based on cultural symbolism and proposed by the Chinese design teams (Eccles et al. 2010), showing the need for cultural knowledge. Without the knowledge and cultural sensitivity of the CCDI architects, the project is unlikely to have been such a success. Arup significantly increased their footprint in China in the subsequent years, with 25% of their staff being based in China (Eccles et al. 2010, pg. 13), indicating that they did heed that lesson. Such understanding will have been invaluable for their expansion in China.
2. Innovative Ideas/Related Risks: On one hand, they learned to innovatively utilise cutting-edge materials and structures, giving the experience and confidence to use them in the future. Additionally, it was also a lesson in the risk involved with utilizing innovative technologies. Arup's choice of selecting such innovative materials carried a significant risk as it could require a redesign if the structure was not deemed safe (Eccles et al. 2010, pg. 9). Despite this, they went ahead with it, applying risk management structures to prove the structures' safety (Eccles et al. 2010, pg. 9). It taught Arup that applying novel ideas can be advantageous to the project, provided that risk is managed properly.
3. Tools and Techniques: Arup has learned a lot from the use of tools such as rapid prototyping and SPeAR, both tools that enabled the project to succeed (Eccles et al. 2010). Especially the use of SPeAR on a design that was explicitly sustainable would have been an invaluable lesson, since Arup as a company has stated that sustainability is very important for them (Arup, n.d.).

4. Allowing ideas to change: At the beginning of the project, the PTW Architects and Arup team put in a significant amount of effort into their design. Even though their design was of high quality, they were convinced by the release of the Bird's Nest Stadium that going with CCDI's idea would produce better results (Eccles et al. 2010, pg. 5). This is a big lesson that sometimes abandoning a design is necessary to get a better end-result.

8. Conclusion and Recommendations

After analysing the case study by Eccles et al. (2010) and other sources, we have come up with solutions to the assignment questions. Additionally, we have gained a deeper appreciation of project management and its role in a company.

We have determined some of the major accomplishments (e.g. meeting fixed deadline), innovations (e.g. holistic sustainable design) and challenges (e.g. cultural misunderstanding). Analysing the project's success, we found practices that helped complete the project (e.g. the use of interface management), Arup's practices to encourage high-quality work (e.g. company culture) and lessons learned from this project (e.g. allowing designs to change).

9. References:

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10. Peer Marks:

	Shweta	Yiling (Lynn)	Hannes	Marsel	Jingwen (Alissa)	Thomas	Xuhua
Participation (3)	3	2.5	3	2.5	2.5	2.5	2.5
Quality of Posts (3)	3	2.5	3	3	2	2	3
Communication (3)	3	3	2.5	2.5	3	2.5	2.5

Following the schedule (1)	1	1	1	1	1	0.5	1
Total (10)	10	9	9.5	9	8.5	7.5	9

11. Lessons Learned

This project provided the opportunity to analyse a large, successful project. During this project, PMs should have an overall perspective of the project and guide team members to follow the schedule to analyse the project from many aspects. How to encourage members to seek unique information can be challenging.

As this project's scope is relatively large, members may have misunderstanding or lack of awareness of some aspects. If this situation could not be resolved through information searching or group discussion, its necessary to seek the help from course tutors. On top of this, summarising the key arguments after completing discussions for a task help integrate information, allowing later tasks could easily refer to the summary. Nevertheless, due to the large scope of this project and time constraints, there may be some disagreements among some answers. To resolve this, PMs should take the responsibility to select the final answers based on the group's consensus.