The management challenges of building a world cup stadium in the Amazon – the case of the Amazon arena (Brazil)

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ABSTRACT

Purpose of this paper
The purpose of this paper is to present the management challenges of building the 44,000-seat Amazon Arena in Manaus, a city located in the rain forest and reached only by river or air.

Design/methodology/approach
Upon showing the difficulties of working in an environment of complicate logistics and under extreme temperatures combined with high relative humidity of air and continuous rainfall, the authors approach the advanced cost engineering concepts employed by the general contractor to ensure satisfactory production rates and to meet the original tight schedule. Scope changes imposed by FIFA during the construction period — such as adherence to LEED energy efficiency requirements and adoption of new visibility parameters —, and many change orders arisen due to poor preliminary design forced the contractor to resort to a state-of-the-art method of measuring and improving productivities based on lean construction philosophy, as well as 4D BIM technology to monitor the progress of job.

Findings
As a conclusion, the lean construction methodology proved to be efficient in such an audacious project, especially due to the large repetition of the precast concrete operations.

Keywords: Lean construction, productivity, 4D BIM, stadium, sports arena.
1. INTRODUCTION

Brazil is preparing to host the International Federation of Association Football (FIFA) World Cup in 2014 and it faces a series of challenges to be overcome so that the event takes place. For the first time a World Cup will be held in 12 host cities spread over a country of continental dimensions.

When it decided to hold an event of such magnitude, Brazil has taken a great responsibility to reform their stadiums - or completely rebuild them - difficult task due to narrowness of deadline, due to the projects' complexity, the high resources involved and the political interference that obviously is present.

In Manaus, one of the twelve host cities, the Amazon Arena is being built, a stadium with capacity for 44,500 spectators and a bold engineering project which highlights the many precast elements and the complex metallic facade structure and roof, covered with membrane. The Arena is now one of the largest construction projects in Brazil.

The only one host city of the Northern Region, located in the middle of the Amazon Rainforest and accessible only by boat and air, Manaus has climatic conditions that considerably reduce the yield in relation to the reference ratio in the country. This is mainly due to high temperatures (between 24 °C and 37 °C), relative humidity (between 76% and 89%) and rainfall of 2300 mm/year in the region. With these factors the work cost estimates become complex. Another aggravating factor in the work's execution is the low qualification of local labor force and high turnover (now around 11.4%).

Besides the natural difficulties of logistics and time, there were several changes in the project scope imposed by FIFA after the work was contracted, causing a strong impact on the project's cost, which is a state public work. Even with the increase of service and cost, the construction company remained strong in order to meet a non-renewable deadline.

2. CONTRACT

The construction of the Amazon Arena is a public work bid by the Amazon State, according to national legislation, from a preliminary design. The contract scope includes the demolition of the existing stadium, the final design development and construction of the new arena.

The 500-million Brazilian reais (300-million USD) unit price contract was adjudicated to Andrade Gutierrez, a Brazilian general contractor. The contract stipulates an implementation period of 36 months, with completion in June 2013. It is worth noting that at the time of contracting the work, it was not yet known which of the 12 cities would host the Confederations Cup, a FIFA tournament to be held in June 2013. If Manaus was one of
those chosen, the work completion would take place just at the time of the competition.

The World Cup stadiums were almost entirely bid in 2009, from a conceptual design made in accordance with the FIFA 2007 requirements (the same that guided the construction of stadiums in South Africa last World Cup).

3. DESIGN

The stadium final design was contracted by Andrade Gutierrez to the German office GMP (Architekten von Gerkan, Marg und Partner). The stadium is a modern multipurpose arena, for sports, leisure and shopping. The aim is that the place be frequented by the public throughout the week, and not just during sporting and cultural events (Figure 58.1).

![Amazon Arena](source: Andrade Gutierrez)

The design incorporates advanced concepts of sustainable architecture, which highlights the collecting rain water system—captured by a drain on the roof, the water will be stored in a reservoir and will be used for lawn irrigation and flush water of the bathrooms. The project meets the requirement of Leadership in Energy and Environmental Design (LEED) certification awarded by the Green Building Council, which certifies the sustainability of the construction, from the conception to its...
operation and maintenance. Moreover, the contractor managed to reuse more than 95% of demolished/removed material from the previous stadium, a major environmental responsibility action.

The stadium has a circular shape, comprising two concrete rings where the seats will be installed. The metallic structure (façade and roof) is covered by a polytetrafluoroethylene (PTFE) membrane—which lacks of domestic suppliers. Such structure is based on an indigenous basket, consisting of welded box beams. These beams do not have standard commercial format, thus being custom-made for the arena. The connections between the beams are very complex—the tridimensional façade-roof connection weld, for example, needs 10 isometric views to be fully depicted. The structure is not self-supporting during the assembly of the beams; only at the final stage, when the top pieces (compression stress) are placed, is that the scaffolding may be removed. The sequence of assembly has been previously and carefully defined by the designers and drives the whole planning of the field operations.

Another point of great difficulty is to build the precast bleachers steps since they have large dimensional variations among themselves, thus requiring constant adjustments of metallic forms in its implementation.

4. CONSTRUCTION

The construction planning had to take into account realistic productivity rates, which are, as explained previously, notably lower than in other host cities. Because the intense atmospheric precipitation and which are frequent, almost daily, there are several service disruptions during the day, with time loss at work and negative impact on the overall productivity.

There is a shortage of skilled professionals in Manaus region, where major infrastructure projects are not frequent. Because of the unavailability of workers, the solution was to create on-site schools to prepare all sorts of construction professionals, e.g., cement masons, carpenters and equipment operators.

Given the distance from Manaus to major production centers in the country (approximately 3,500 km from São Paulo) and the large quantity involved (67,000 cubic meters of concrete), the general contractor decided to install plants of precast concrete, reinforcing steel and formwork on the construction site. The precast concrete plant currently produces 880 pieces/month, encompassing tiers, steps, slabs and inclined beams. This quantity and variety would be impossible to get from local suppliers (Figure 58.2).
5. PLANNING

The managing team decided for a use 4D Building Information Modeling (4D BIM). First, the project is illustrated in 3D with the use of ArchCad and Google Sketchup softwares and thereafter coupled to Microsoft Project to reach the fourth dimension (3D plus time) (Figure 58.3). The BIM technique is still in its infancy in Brazil, especially in 4D mode.

There are many gains with BIM: better logistics definition, identifying interferences, accessibility checking, scenarios simulation and work status view. Moreover, it is possible to generate activities animation for field teams’ instruction.
6. COST AND SCOPE PROBLEMS

The scope problems in the Amazon Arena have many causes, however almost all of them derived from a common root: the commitment term signed between FIFA and each host city. The term is very clear in stating that the host cities are required to comply with all technical requirements, "reserving to the Organizing Committee and FIFA the right to modify, delete or add new requirements at any time until the date of the competition" (Host City Agreement, 2008). This means that the World Cup Local Organizing Committee (LOC) and FIFA, besides not spending a penny for the construction of stadiums, they may at any time require changes in the original project, even if it generates additional cost to those responsible for the construction, which are the state governments or the right holders to utilize the stadium in the case of public-private partnerships.

It is precisely during the project detailing that such specification changes arise dictated by LOC or FIFA. In Brazil, the so-called visibility curve of the stadium was changed in the executive project phase to adapt the stands to new parameters. The advertising signs, for example, have their height increased from 0.9 m to 1m, as well as the distance to the field boundary line reduced from 5m to 4m (Figure 58.5). As it is clear that all seats of the Arena have full view of the four field lines, a quick geometry exercise shows that this simple dimensional change affects the stands...
arrangement and, therefore, there are many reflections on the size of the steps, amount of seats, location of foundation blocks, and redesign of some facilities.

Yet in order to improve visibility, FIFA has also determined that from any place in the stadium, fans have to see the ball at a height of 20m from the ground. In the case of Manaus, such preciousness caused a lowering of the field grade by 4m, impacting on excavation volume and soil transportation, the architectural solution of stairs, ramps and access in general, as well as the emerging need to implement a retaining wall, obviously affecting the time and cost of the stadium work (Figures 58.4 and 58.5).

Figure 58.4 – Adjustment of the visibility curve due to the advertising signs (source: Andrade Gutierrez)

Figure 58.5 – Lowering the field grade to fit the visibility curve (source: Andrade Gutierrez)
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After all scope changes and project adjustments, the job quantities rose considerably, as shown in Table 1, but the contractor was not allowed time extension for obvious reasons.

Table 58.1 – Original and final quantities

<table>
<thead>
<tr>
<th>DESCRIPTION</th>
<th>UN</th>
<th>PRELIMINARY DESIGN</th>
<th>FINAL DESIGN</th>
</tr>
</thead>
<tbody>
<tr>
<td>Demolition</td>
<td>m³</td>
<td>17497.00</td>
<td>23846.83</td>
</tr>
<tr>
<td>Earthmoving</td>
<td>m³</td>
<td>65,000</td>
<td>408,000</td>
</tr>
<tr>
<td>Foundation piles</td>
<td>m</td>
<td>22,000</td>
<td>40,000</td>
</tr>
<tr>
<td>Concrete</td>
<td>m³</td>
<td>58,000</td>
<td>67,000</td>
</tr>
<tr>
<td>Reinforcing steel</td>
<td>ton</td>
<td>4,000</td>
<td>5,000</td>
</tr>
<tr>
<td>Formwork</td>
<td>m²</td>
<td>140,000</td>
<td>228,000</td>
</tr>
<tr>
<td>Steel structure</td>
<td>ton</td>
<td>3,900</td>
<td>6,300</td>
</tr>
<tr>
<td>PTFE membrane</td>
<td>m²</td>
<td>15,700</td>
<td>31,000</td>
</tr>
</tbody>
</table>

Another change in scope occurred from the stadium requirement to comply with the LEED certification, which shows the sustainable profile from the project’s phase through construction and even operation of a construction. This imposition resulted in a representative increase in costs.

With all the mishaps of scope and cost, the only way the contractor could still meet the contract deadline was resorting to: (i) value engineering; (ii) lean construction.

8. VALUE ENGINEERING

Several Value Engineering analyses were prepared for negotiation with the Owner. The idea is to use innovative technical solutions to offset the impact of work acceleration, ensuring the construction economic feasibility and the financial result for the contractor.

The Value Engineering studies were performed to select the types of slabs, containment, cranes, poles and drainage system of the construction, with improvement in functionality and at a lower cost.

In the specific case study of the cranes, the original solution provided by the Owner in the tender documents (6 fixed cranes with H=45m and jib of 55m) would not be able to reach the required production of laying the precast elements. Actually, the conceptual design was wrong and the number of cranes really needed would add up to eight. When the economic analysis of this solution was done, it was observed that two
cranes on rails could be used, one on the east side and one on the west side, which would provide a cost reduction of approximately 8% if compared to the 8 fixed cranes. The two rail-mounted cranes are more flexible and allow better field coordination. This solution was approved by the Owner. Cranes on rails had never been used in this region of the country.

Another Value Engineering analysis was the change from the original cast-in-place beams and slabs to precast elements, thus allowing greater flexibility in the construction and work progress even in rainy days. Furthermore, shoring was no longer necessary and more room was left to concurrent field activities.

9. LEAN SOLUTION

Due to the fact that the project completion date cannot be postponed, in spite of all increases in scope and cost, the managing team innovated by applying the Lean Operational Excellence (LOE) principles in order to reduce waste and generate a quick and effective management of work processes. Increases in production rates and cost reduction are the consequences of these principles.

Lean production is based on reducing waste focusing on the activities prioritization that add value, with a focus on eliminating any kind of work that is considered unnecessary in the production of a determined product in order to achieve productivity increase.

The Lean Operational Excellence goes beyond typical Lean Construction, covering items such as suppliers' management, logistics, personnel management, continuous improvement and facility management (Barros, Alves and Fernandes, 2012).

The activities of a certain operation are divided into three types (Baudan, 2005):

- Value-adding activities: operations that are strictly necessary for the work completion;
- Hidden or necessary waste: auxiliary operations necessary to conduct the activities that add value;
- Evident waste: operations that occur, but should be eliminated, such as waiting, storage and defects correction.

Specifically for the construction industry, there were nine types of waste (Hirano, 2009): waiting, moving, unnecessary processes, unused area, transportation, inventory, overproduction, defects and delays.

Until the present date, the Lean was applied to four productive fronts—reinforcing steel plant, precast plant, cast-in-place concrete and laboratory—, as well to support and administration areas.

In the reinforcing steel plant, for example, where the cutting, folding, and steel assembly take place, with an average production of 600 ton/month, LOE use was designed based on a diagnosis of the plant work flow. The steps for implementation in this area were:
i. Definition of product families and manufacturing flowchart – mapping all service activities of helical piling, precast stairs/beams and foundation blocks;

ii. Qualitative assessment of waste – the most common waste was found at the helical piling;

iii. Measurement of distances – every displacement of the crew was measured and plotted (Figure 58.6);

iv. Filming of activities – a time analysis was performed for each worker, in order to identify time distribution minute by minute. It was found that 40% of operations add value, 20% were hidden waste and 20% were evident waste (Figure 58.6);

v. Layout optimization – It was observed that the spatial arrangement of the storage bays, work tables and intermediate storage location was not the most appropriate. By optimizing the layout, the team reached a reduction of 87% in the total displacement of the workers;

vi. Preparation of operational procedures – the procedures show the work fronts, supply routes and production flows, with photographs of the actions and the time allotted for each operation of each worker;

vii. Mounting of control boards – upon issuing the operational procedures, charts were used to keep track of production rhythm and to generate performance indicators. These charts show the production status at any time of day in comparison to the goal via kanban cards. Whenever a goal is not accomplished, the kanban card is not rotated and an action plan is instantly drawn up to address the root cause of that problem;

viii. Losses management – using lean thinking, it was possible to prepare steel cutting plans whose waste was cut down by 50%;

ix. Visual signs (andon) – color signs show the foremen whether the workers are reaching production targets during the day. This allows quick reaction to problems, creating greater efficiency of supporting staff.
10. CONCLUSION

Under the contractual point of view, which is taken as a lesson learned is that the explicit authorization for the local organizing committee and FIFA have the right to modify, delete or add new requirements at any time represents a major risk for the stadiums owners and construction companies, which brings impact to cost and the construction deadline.

With this real likelihood of deliberate change of scope, it is necessary that the projects are budgeted for time and money contingencies with a reasonable managed reserve not always available to those who finance and contract the projects.

A large size construction job which takes place in an adverse weather place, with low-skilled labor, low availability of workers, long distance from production centers and frequent change orders and scope adjustments can only be mastered through an exhaustive process of planning and control.

In the case of the Amazon Arena, where external variables are numerous, the application of lean production concepts have brought enormous benefits to the job, allowing the management team to better control the progress, improve the communication flow, increase productivity and adapt the processes to focus on waste reduction. The implementation of Lean Operational Excellence provided a productivity increase of approximately 20% in the service fronts where it was applied.

Moreover, the use of Value Engineering has brought more economical solutions for the construction, while not jeopardizing quality and schedule.

Figure 58.6 – Spaghetti diagram, filming and steel plant waste distribution
11. REFERENCES


Host City Agreement, 2008, FIFA.
