Sustainable sport venue design

P5 presentation – Felix Dorst

10-4-2018
Olympic legacy

Athens Olympics 2004

Beijing Olympics 2008
Temporary Olympic venues

Rio Olympics 2016

Pyongyang Winter Olympics 2018
Problem statement

Olympic venues have a reputation to leave a bad legacy

Temporary venues are increasingly common

Venues consists mostly of load bearing structure and facade, and almost exclusively built from steel

Temporary venues use a lot of material in a short amount of time
How can a design strategy for a temporary and demountable sports arena for the Olympic Games be optimized to a post-event use in steel construction?
Literature

1 Legacy
2 Post-event uses
3 Demountable
4 Conclusions
Legacy Olympics

Material

People

Venues

Olympic Games

Temporary time
Post-event uses of sport venues venues

1 Relocate
Basketball London

2 Adapt
Aqua centre Rio

1 Upcycle
Water polo London

1 Recycle
Sydney Olympics
## Post-event uses: unexpected outcome

<table>
<thead>
<tr>
<th>Venue</th>
<th>Intended post event use</th>
<th>Sucess?</th>
<th>Actual legacy</th>
</tr>
</thead>
<tbody>
<tr>
<td>Aqua centre Rio 2016</td>
<td>Transformation to 4 schools</td>
<td>X</td>
<td>Abandoned</td>
</tr>
<tr>
<td></td>
<td></td>
<td></td>
<td>- Too expensive</td>
</tr>
<tr>
<td></td>
<td></td>
<td></td>
<td>- One strategy</td>
</tr>
<tr>
<td>Basketball London 2012</td>
<td>Relocate as travelling arena</td>
<td>X</td>
<td>Disassembled</td>
</tr>
<tr>
<td></td>
<td></td>
<td></td>
<td>- Never used again</td>
</tr>
<tr>
<td></td>
<td></td>
<td></td>
<td>- One strategy</td>
</tr>
<tr>
<td>Olympic stadium London 2012</td>
<td>Reduce size &amp; upcycle</td>
<td>✓</td>
<td>Reduced in size</td>
</tr>
<tr>
<td></td>
<td></td>
<td></td>
<td>- No record of upcycled elements</td>
</tr>
<tr>
<td></td>
<td></td>
<td></td>
<td>- Multiple strategies</td>
</tr>
</tbody>
</table>
Disassembly & transportation

Demountable

- Minimize number of tools
- Minimize number of tasks
- Minimize time to disassemble
Circular economy of steel construction

Steel is the most suitable
- Standardization is possible
- Weight/strength ratio
- much potential

barriers of steel
- Likely to be recycled
- Lack of documentation
- Not enough standardization
- increasing value of scrap steel
Conclusions literature

- There are four possible post-event strategies to reuse a temporary sports arena.
- Selecting a single type of strategy has a low rate of success.
- Demountability of venues and transport are essential factors to reuse a temporary sports arena.
Requirements

1 Design focus
2 Structural requirements
3 Reuse strategy
Design focus

Apply findings to case

- Volleyball arena Paris Olympics 2024

General requirements
- Capacity for 17,000 and 5,500 visitors in one volume (Seating bowl shape)
- Enclosed from wind, rain and direct sunlight, column-less space

Design focus
- Volume design, general shape
- Steel load bearing structure
Structure requirements

- Simple structure > determined by research from case studies
- **Demountable**: Bolted steel connections
- Optimized towards reuse
- Form follows function: shape is formed by the construction
**Structure** portal construction

**Portal construction (shear connection)**

- More material & footprint
- Simpler connection
- Simple disassembly

**Portal construction (moment connection)**

- Less material & footprint
- Complicated connection
- Difficult disassembly
Structure **roof construction**

1. Stability every other portal construction...
2. ...leads to connected trusses (space trusses)
3. Slanted roof: alternating angled trusses
4. Spacers
Structure: column construction

Alternating heights, and irregular placement

Modular built trusses, interchangeable and repeatable
Structure hand calculations

- Height of the roof construction (x) plotted against the deflection (y)
  - 400 mm

- Height of the roof construction (x) plotted against the profile surface area (y)
  - 16500 mm²

- HEB 300+
- HEA 450+
- etc...
Post-event strategy

1 Relocate
   a. whole
   b. transformed

2 Adapt
to other building formats

3 Upcycle
construction into reusable members

4 Recycle
as little as possible

Design requirements
Relocate whole - requirements

Technical elaboration:
- Minimizes number of tools
- Minimizes number of tasks
- Minimizes time to disassemble

Transport restrictions of shipping container:
Maximum element dimensions:
Height: 2,59 m
Width: 2,44 m
Length: 12,19 m

Transport restrictions of road transport:
Weight limit of element:
Weight: 40 t
Relocate & transform - requirements

**Relocate & transform**

**Duplicate members**
- Technical elaboration
  - Standardized profiles
  - Standardized connections
  - Similar measurements

**Adaptable component use**
- Connections
  - Interchangeable
  - Alternative configurations

**Documentation of components**
- Database containing:
  - Member dimensions
  - Member categorization
  - Connection method

**Design requirements**

- Demountable
- Transportable
- Parametric environment

Parametric environment
Adapt to other building format - requirements

Building formats

Simplification of 3 building formats
- Portal construction
- High rise construction
- Truss construction

Containing
- Dimensions
- Connection method
- Common profiles

Adaptable connections

Connections
- Multi-angled connections

Adjust geometry accordingly

Input data:
- For example: Commercial floor height 4.2 m
- Multiples of
- Generalize towards standard measurements (1m)

Design requirements

Demountable
Transportable
Parametric environment
building format requirements

Parametric environment
Upcycle - requirements

Documentation of components

Database containing:
- Member dimensions
- Member categorization
- Connection method
- Physical adjustments
- Repetition

Design requirements

Demountable  Transportable  Parametric environment  Building format requirements  Reusable members  Visual tool
Conclusions

- Selecting a single type of strategy has a low rate of success

- Demountability of venues and transport are essential factors to reuse a temporary sports arena
Design

1 Validation method
2 Design overview
3 Technical elaboration
4 Parametric?? nope
5 Results
Design overview

- Façade – PVC membrane
- Steel load bearing construction
- Temporary seating Bowl 13,000 + 5,500 capacity

Design implications
Design implications
Design implications
Design implications
Design construction

Design implications
Design facade

- Façade – PVC membrane
- Steel load bearing construction
- Scaffolding
- Seating bowl

Design implications
Research by design

Design requirements
Validation Relocate & transform

- We need to know:
  - Database on members in the structure
    - Member length
    - Type of member (category)
    - Connection
  - Exact info of three rearranged iterations of the design
  - A way to compare those with the original
Validation Relocate & transform

Input:
- Dimensions LxWxH
- Shape (curved)

Output:
- Altered shape towards standardization
- required construction density & height

Design implications
- Demountable
- Lightweight
- Parametric environment
Validation Adapt to other building format

- Steel portal construction (supermarket etc.)
- High rise construction (offices etc.)
- Steel truss (Concert hall etc.)
Validation Adapt to steel portal construction

1. Research
2. Implication on design
3. Design
4. Post event use
   (34% of the steel reused)

Design implications
- Demountable
- Lightweight
- Parametric environment
- Building format requirements
Validation Upcycle

- Similar members (count > 50)
- Required alterations on member
- Visual tool

**Design implications**
- Demountable
- Lightweight
- Parametric environment
- Building format requirements
- Reusable members
- Visual tool
Validation Upcycle

### Design implications

- **Demountable**
- **Lightweight**
- **Parametric environment**
- **Building format requirements**
- **Reusable members**
- **Visual tool**

### Count boundary

<table>
<thead>
<tr>
<th>Member length</th>
<th>Count</th>
<th>Combined length</th>
</tr>
</thead>
<tbody>
<tr>
<td>&gt;50 2.7 m</td>
<td>410</td>
<td>1107 m</td>
</tr>
<tr>
<td>&gt;50 3.94 m</td>
<td>64</td>
<td>252.16 m</td>
</tr>
<tr>
<td>&gt;50 4.3 m</td>
<td>494</td>
<td>21242 m</td>
</tr>
<tr>
<td>&gt;50 5.6 m</td>
<td>529</td>
<td>2962.4 m</td>
</tr>
<tr>
<td>... etc. (5 more)</td>
<td>... etc.</td>
<td>... etc.</td>
</tr>
<tr>
<td><strong>Total</strong></td>
<td></td>
<td><strong>8849.69 m</strong></td>
</tr>
<tr>
<td>&lt;50 0.34 m</td>
<td>2</td>
<td>0.68 m</td>
</tr>
<tr>
<td>&lt;50 0.54 m</td>
<td>2</td>
<td>1.08 m</td>
</tr>
<tr>
<td>&lt;50 0.57 m</td>
<td>2</td>
<td>1.14 m</td>
</tr>
<tr>
<td>&lt;50 0.61 m</td>
<td>2</td>
<td>1.22 m</td>
</tr>
<tr>
<td>... etc. (332 more)</td>
<td>... etc.</td>
<td>... etc.</td>
</tr>
<tr>
<td><strong>Total</strong></td>
<td></td>
<td><strong>8566.86 m</strong></td>
</tr>
<tr>
<td><strong>Percentage (count &gt;50)</strong> in meters steel fit for upcycling</td>
<td></td>
<td><strong>53.9% (in m)</strong></td>
</tr>
</tbody>
</table>
Validation Upcycle visual tool

Design implications

- Demountable
- Lightweight
- Parametric environment
- Building format requirements
- Reusable members
- Visual tool
Conclusions

How can a **design strategy** for a **temporary and demountable** sports arena for the Olympic Games be optimized to a **post-event use in steel construction**?
Conclusions

- Account for multiple scenarios of reuse: Relocate, Adapt, Upcycle and recycle
- Design decisions must be based on information from the steel construction industry
- Computational tools and documentation must be used to guide the design process and to assess the influence of design decisions
Conclusions further recommendations

- A computational and parametric design lends itself for further optimization
- Location specific demands could help to embed the reuse strategies
Thank you!

Sustainable sport venue design - Felix Dorst
Reuse requirements goals

Traditional building revenue

Required building revenue