Whole Building Life Cycle Assessment: Three Olympic Venues

Presentation Slides

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CIVL 498C
April 6, 2011

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OVERVIEW

• Introduction
  • What is LCA?
  • How can it help?
  • Goal and Scope
• Tools and methodology
  • Software
• Results
  • Environmental impact potential
  • Sensitivity analysis
  • Uncertainties
• Conclusion
  • London 2012
  • Recommendations
  • Where do we go from here?
WHAT IS LCA?

**Life Cycle Assessment**
- A technique used to analyze and assess environmental impacts associated with all the stages of a product's life within a chosen system boundary

Diagram:
- Goal and Scope
  - Inventory Analysis
  - Impact Assessment
- Interpretation
EVERY PRODUCT'S LIFE CYCLE IS CREATED BY THE CONNECTIONS BETWEEN PROCESSES...
AND EACH PROCESS HAS INPUTS AND OUTPUTS TO WHICH IMPACT CAN BE ASSOCIATED
WHAT IS LCA?

• We can quantify and group these impacts into different environmental impact categories

• “Environmental accounting”

• Gaining attention as environmental stewardship increases

• ISO 14040, ISO 14044
• Evaluate the potential impacts associated with these emissions
• Interpreting the results within the context and scope of the study
• Get LCA data to facilitate more LCA data
- 3 Olympic Venues
- Cradle to gate
- Structure and envelope
Everyone !!!
Richmond Olympic Oval
- Officially opened on December 12, 2008
- Built to LEED Silver standards
- Maintained a 400m skating surface during the Olympics
- Hosted all speed skating events
- Now serves as a general athletics and convention center
**Doug Mitchell Thunderbird Sports Center**

- Opened on July 7, 2008
- Built to LEED Silver standards
- Renovation and Reconstruction of the Thunderbird Winter Sports Complex
- Hosted Ice and Sledge Hockey Events
- Home of the UBC Thunderbirds Hockey Teams
Thunderbird Winter Sports Center

- Originally opened in 1963
- Expanded in 1968/1969
- 3 full-size rinks, curling arena and squash/handball courts

- Home of Canada’s first national hockey team (1963)
- Father Bauer Arena was retained by the Doug Mitchell Center and used as a practice rink for the Olympics
The Father Bauer Arena is a portion of the current Doug Mitchell Thunderbird Sports Centre that remains from the original Thunderbird Arena construction.

- Life Cycle Impacts of Father Bauer Arena apportioned to LCA of Old Thunderbird as it was a part of the initial development.
METHODOLOGY

Goal and Scope

Inventory Analysis

Impact Assessment

Interpretation
METHODOLOGY

- Takeoffs
- Athena Inputs
- BoM Results
- Athena LCI/TRACI
- IA Profiles

Assumptions

Assumptions
METHODOLOGY

- TOOLS USED -

Takeoffs
Using On-Screen Takeoff
Takeoff Examples

METHODOLOGY
- TOOLS USED -
METHODOLOGY
- TOOLS USED -

Takeoff Examples

Linear Conditions
Athena Inputs
Athena Impact Estimator 4.1

Inputs from Inputs Assumption Document
Findings entered into IE
Used to generate BoM
• Helps with Impact Estimator Inputs
• Provides transparency for all assumptions used during the project
# METHODOLOGY

## Bill of Materials Output

<table>
<thead>
<tr>
<th>Material</th>
<th>Quantity</th>
<th>Unit</th>
<th>Columns/Beams</th>
<th>Floors</th>
<th>Roofing</th>
<th>Foundations</th>
<th>Walls</th>
</tr>
</thead>
<tbody>
<tr>
<td>#15 Organic Felt</td>
<td>99836.10 m2</td>
<td>m2</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>1/2&quot; Moisture Resistant Gypsum</td>
<td>1169.39 m2</td>
<td>m2</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>1/2&quot; Regular Gypsum</td>
<td>812.44 m2</td>
<td>m2</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>3 mil Polyethylene</td>
<td>224.38 m2</td>
<td>m2</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Aluminum</td>
<td>8.34 Tonnes</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Ballast (aggregate stone)</td>
<td>6058570.25 kg</td>
<td>kg</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Batt. Fiberglass</td>
<td>449.55 m2</td>
<td>m2 (25mm)</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Blown Cellulose</td>
<td>11297.36 m2</td>
<td>m2 (25mm)</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Cedar Wood Shiplap Siding</td>
<td>1850.52 m2</td>
<td>m2</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Cedar Wood Tongue and Bevel</td>
<td>69.03 m2</td>
<td>m2</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Commercial(26 ga.) Steel</td>
<td>1488.49 m2</td>
<td>m2</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Concrete 20 MPa (flyash av)</td>
<td>3589.31 m3</td>
<td>m3</td>
<td></td>
<td>1652.93</td>
<td>1930.71</td>
<td></td>
<td></td>
</tr>
<tr>
<td>Concrete 30 MPa (flyash av)</td>
<td>168.97 m3</td>
<td>m3</td>
<td></td>
<td>163.32</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Concrete Blocks</td>
<td>68977.12 Blocks</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>EPDM membrane (black, 60mil)</td>
<td>722.53 kg</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Expanded Polystyrene</td>
<td>361.66 m2</td>
<td>m2 (25mm)</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
</tbody>
</table>
What do we do with all this information??

- Select impact categories
- Category indicators
Selected Impact Categories include:

- Fossil Fuel Consumption
- Weighted Resource Depletion
- Smog Formation
- Global Warming Potential
- Ozone Layer Depletion
- Eutrophication Potential
- Human Health Respiratory Effects
- Acidification Potential

Source: http://www.epa.gov/nrmrl/std/sab/traci/
METHODOLOGY

- Fossil Fuel Consumption

  Category Indicator: MJ

  - All fossil fuel, direct and indirect, used to transform or transport raw materials into products and buildings
  - Characterized by Athena
  - Expressed in fossil fuel consumption
**WEIGHTED RESOURCE USE**

**Category Indicator:** kg of Resources

- The ecological weight of resources used on site
- Characterized by:
  - Land use and areas impacted
  - Duration of impacts
  - Ecological significance
• Smog Formation

Category Indicator: kg NO\textsubscript{x} equivalent

• Ground level ozone created through reaction of VOCs and NO\textsubscript{x} in the presence of sunlight

• Effects human health

• Can reduce crop yield due to lack of sufficient photosynthesis

• Smog is worse in densely populated regions, especially in valley areas

= VANCOUVER

• Global Warming Potential

**Category Indicator: kg CO\textsubscript{2} equivalent**

• Capacity to absorb infrared radiation, which heats the atmosphere

• Characterized by Intergovernmental Panel on Climate Change (IPCC)

• 11 of the past 12 years are among the warmest since 1850

• Arctic may have its first ice-free summer by 2040

METHODOLOGY

- Ozone Layer Depletion

  **Category Indicator:** kg CFC-11 equivalent

  - Destruction of the upper atmospheric ozone column due to the emissions of substances (HFCs and Halons) relative to CFC-11
  
  - Characterized by World Meteorological Organization (WMO)
  
  - Increased UVB reaching the earth

  www.dilg.gov.ph
METHODOLOGY

• Eutrophication Potential

Category Indicator: kg Nitrogen equivalent

• Aquatic Eutrophication occurs when bodies of water are enriched with nutrients from waste water discharge resulting in algae over growth

• Characterized by US EPA

• Kills fish and shellfish

• Toxicity to human, marine mammals, livestock

• Effects recreation, industry, and ecosystem
METHODOLOGY

• Human Health Respiratory Effects

Category Indicator: kg PM2.5 equivalent

• Exposure to airborne particulate matter less than 2.5 μm in size

• Characterized by USA EPA

• Effects human health
  • Coughing, wheezing
  • Worsens asthma, heart disease, pneumonia

• **Acidification Potential**

  **Category Indicator:** moles of H+ equivalent

  • Capacity to form H+ ions from SO$_2$ and NO$_x$, increasing acidity of soil and water systems

  • Characterized by US EPA

  • Ecosystem changes

  • Plant and animal mortality
METHODOLOGY

- Interpreting Results
  - Grouping Impacts
    - Local, Regional, Global
  - Normalizing Impacts
    - Benchmark comparisons

- Completeness Check – Sensitivity Analysis
  - How sensitive/responsive certain categories are to changes in the model
  - What contribute most to the system (extraction, manufacturing, end of life)
Study Results

Building Characteristics
# BUILDING CHARACTERISTICS

- Thunderbird Old -

<table>
<thead>
<tr>
<th>Building System</th>
<th>Specific Building Characteristics</th>
</tr>
</thead>
<tbody>
<tr>
<td><strong>Structure</strong></td>
<td>Concrete and steel columns supporting concrete suspended slabs</td>
</tr>
<tr>
<td><strong>Floors</strong></td>
<td>Ground Floor: Concrete slab on grade; First Floor: Suspended slab</td>
</tr>
<tr>
<td><strong>Exterior Walls</strong></td>
<td>8” Concrete block with several smaller sections of cast-in-place walls</td>
</tr>
<tr>
<td><strong>Interior Walls</strong></td>
<td>8” and 6” Concrete block construction with some wood stud partitions</td>
</tr>
<tr>
<td><strong>Windows</strong></td>
<td>All windows assumed to be standard glazing</td>
</tr>
<tr>
<td><strong>Roof</strong></td>
<td>Built-up roofs, Glulam and steel trusses</td>
</tr>
</tbody>
</table>
## Building Characteristics

- **Thunderbird New**

### Structure
- Reinforced Concrete Frame, Concrete Block

### Floors
- Foundation: Concrete Slab on grade; floors are precast concrete double T

### Exterior Walls
- Foundation: Cast-in-place walls; Ground and the rest of the floors: concrete tilt-up and block, and wood stud

### Interior Walls
- Foundation: Cast-in-place walls; Ground and First Floors: wood stud with plywood sheating

### Windows
- All windows operable with aluminum frame and standard glazing

### Roof
- Concrete Precast Double T
**BUILDING CHARACTERISTICS - Richmond Oval -**

<table>
<thead>
<tr>
<th>Building System</th>
<th>Specific Building Characteristics</th>
</tr>
</thead>
<tbody>
<tr>
<td><strong>Structure</strong></td>
<td>Concrete columns support concrete suspended slabs and concrete buttresses all with steel reinforcement.</td>
</tr>
<tr>
<td><strong>Floors</strong></td>
<td>Floors are a concrete slab and slab band system, with hollow core concrete panels supporting a significant portion of the activities deck.</td>
</tr>
<tr>
<td><strong>Exterior Walls</strong></td>
<td>North and South sides: fixed curtain wall with no glazing and aluminum frame. On the third floor of the South side, polycarbonate cladding overlays the glass.</td>
</tr>
<tr>
<td><strong>Interior Walls</strong></td>
<td>Mainly steel stud walls with various amounts and types of gypsum board. Also concrete block walls with no envelope material and concrete cast-in-place walls.</td>
</tr>
<tr>
<td><strong>Windows</strong></td>
<td>Interior doors are either solid wood or hollow metal. Exterior doors are either hollow metal or sliding glass.</td>
</tr>
<tr>
<td><strong>Roof</strong></td>
<td>Concrete Precast Double TComposite beams composed of Glulam and structural steel support the main span of the roof, WoodWave engineered structural panels composed mainly of softwood lumber span between the composite beams and are filled with fibrous mineral wool insulation.</td>
</tr>
</tbody>
</table>
Study Results

Impact Categories
IMPACT ASSESSMENT
- Global Warming Potential per Building -

Global Warming Potential

- Thunderbird Old
- Thunderbird New
- Richmond Olympic Oval

Global Warming Potential

- Earthworks
- Construction
- Manufacturing

Tonnes CO² Equivalent

Thunderbird Old
Thunderbird New
Richmond Olympic Oval
IMPACT ASSESSMENT

- Global Warming Potential per Sq. Ft.

**Graph:**

- **Global Warming Potential**

  - **kg CO₂ equivalent/ft²**

  - **Categories:**
    - Thunderbird Old
    - Thunderbird New
    - Richmond Olympic Oval

  - **Graph Legend:**
    - Red: Earthworks
    - Green: Construction
    - Blue: Manufacturing
IMPACT ASSESSMENT
- Weighted Resource Use per Building -

Weighted Resource Use

<table>
<thead>
<tr>
<th>Building</th>
<th>Earthworks</th>
<th>Construction</th>
<th>Manufacturing</th>
</tr>
</thead>
<tbody>
<tr>
<td>Thunderbird Old</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Thunderbird New</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Richmond Olympic</td>
<td></td>
<td></td>
<td></td>
</tr>
</tbody>
</table>

Tonnes

0   100   200   300   400   500   600

Richmond Olympic Oval has the highest weighted resource use.
IMPACT ASSESSMENT
- Weighted Resource Use per Sq.Ft. -

Weighted Resource Use

<table>
<thead>
<tr>
<th>Location</th>
<th>Earthworks</th>
<th>Construction</th>
<th>Manufacturing</th>
</tr>
</thead>
<tbody>
<tr>
<td>Thunderbird Old</td>
<td>700</td>
<td>100</td>
<td>200</td>
</tr>
<tr>
<td>Thunderbird New</td>
<td>200</td>
<td>100</td>
<td>200</td>
</tr>
<tr>
<td>Richmond Olympic</td>
<td>1,200</td>
<td>100</td>
<td>200</td>
</tr>
</tbody>
</table>

kg/ft²
Weighted Resource Use

- UBC Academic Building Average
- Thunderbird Old
- Thunderbird New
- Richmond Olympic Oval

Impact Assessment
UBC Average Comparison

kg/ft²: 0, 100, 200, 300, 400, 500, 600, 700
 IMPACT ASSESSMENT
- Fossil Fuel Consumption per Building -
METHODOLOGY

- Where do we go from here??
  - Normalization
    - Benchmark against average

Fossil Fuel Consumption
Thunderbird Arena (New) = 582 Houses Annual Energy Use

http://oee.nrcan.gc.ca/corporate/statistics/neud/dpa/tablestrends2/res_ca_1_e_4.cfm?attr=0
IMPACT ASSESSMENT
- Fossil Fuel Consumption per Sq.Ft. -

Primary Energy Use

Megajoules/ft$^2$

Thunderbird Old  Thunderbird New  Richmond Olympic Oval

Earthworks  Construction  Manufacturing
IMPACT ASSESSMENT
- UBC Average Comparison -

Primary Energy Consumption

megajoules/ft²

UBC Academic Building Average  Thunderbird Old  Thunderbird New  Richmond Olympic Oval

0  100  200  300  400  500  600
Study Results
Sensitivity Analysis of the Thunderbird Arena (New)

<table>
<thead>
<tr>
<th></th>
<th>+ 10% Rebar</th>
<th>+ 10% 30MPa Concrete</th>
<th>+ 10% Foam, Polyiso</th>
<th>+ 10% Concrete Block</th>
<th>+ 10% PVC Membrane</th>
</tr>
</thead>
<tbody>
<tr>
<td>Fossil Fuel Consump.</td>
<td>0.84%</td>
<td>1.73%</td>
<td>0.24%</td>
<td>0.33%</td>
<td>0.90%</td>
</tr>
<tr>
<td>Weighted Resource</td>
<td>0.18%</td>
<td>6.87%</td>
<td>0.02%</td>
<td>0.03%</td>
<td>0.07%</td>
</tr>
<tr>
<td>Use</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Global Warming</td>
<td>0.39%</td>
<td>3.22%</td>
<td>0.32%</td>
<td>0.45%</td>
<td>0.38%</td>
</tr>
<tr>
<td>Potential</td>
<td>0.39%</td>
<td>3.81%</td>
<td>0.22%</td>
<td>0.57%</td>
<td>0.97%</td>
</tr>
<tr>
<td>Acidification</td>
<td>0.30%</td>
<td>3.72%</td>
<td>0.12%</td>
<td>0.54%</td>
<td>0.39%</td>
</tr>
<tr>
<td>Potential</td>
<td>2.02%</td>
<td>2.06%</td>
<td>0.05%</td>
<td>0.23%</td>
<td>0.13%</td>
</tr>
<tr>
<td>Respiratory Effects</td>
<td>0.00%</td>
<td>5.94%</td>
<td>0.04%</td>
<td>0.62%</td>
<td>0.00%</td>
</tr>
<tr>
<td>Eutrophication</td>
<td>0.10%</td>
<td>5.27%</td>
<td>0.14%</td>
<td>0.58%</td>
<td></td>
</tr>
<tr>
<td>Potential</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Ozone Depletion</td>
<td></td>
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<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Potential</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Smog Potential</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
</tbody>
</table>
SENSITIVITY ANALYSIS

Global Warming Potential

<table>
<thead>
<tr>
<th>Effect</th>
<th>0.38%</th>
<th>0.45%</th>
<th>0.32%</th>
<th>3.22%</th>
<th>0.39%</th>
</tr>
</thead>
<tbody>
<tr>
<td>+ 10% PVC Membrane</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>+ 10% Concrete Block</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>+ 10% Foam, PolyIso</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>+ 10% 30MPa Concrete</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>+ 10% Rebar</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
</tbody>
</table>
SENSITIVITY ANALYSIS
- Functional Areas -

The diagram illustrates the percentage of total building floor area for Thunderbird (old), Thunderbird (new), and Richmond Oval, categorized by various functional areas:

- **Unassigned**
- **Parking**
- **Storage/Utilities**
- **Retail/Concession**
- **Seating**
- **Wash/Change Rooms**
- **Multipurpose Courts/Areas**
- **Multipurpose Rinks**
- **Hallways/Concourses**
- **Administration**

The data shows the proportion of each functional area within each facility.
• First ever life cycle assessment of Olympic Venues
  • To be included in Olympic Games Impact (OGI) Study...

• Addition of Thunderbird to the UBC LCA Database
  • Richmond Oval the beginning of extension into GVRD

![Graph showing differences in impact for various categories and locations.](image)
GLOBAL APPLICATIONS: LONDON 2012

How do we compare?
Entire Scope of Carbon Study
- Pre-games (venues, structures etc.)
- Games (spectators, operations...)
- Legacy (use after Olympics)

Identified 4 venue `biggest hitters`:
- Olympic Park Works = 48%
- Olympic Village = 23%
- Media Centre = 8%
- Stadium/Aquatics Centre = 7%
These buildings do not serve the same function, however...

**RICHMOND OVAL**

Seating: 8000
CO2eq: 23 kilo-tonnes
Tonnes/seat: 2.875

**LONDON 2012 STADIUM**

Seating: 80,000
CO2eq: 129 kilo-tonnes
Tonnes/seat: 1.6125

Given that 55,000 seats in the London Stadium are temporary (and lighter structure), and the heavy earthworks required in Richmond.
Conclusions
LCA is a symptom of the change in the way we design products.

- Our reports are publicly available at the UBC SEEDS Library!
  [http://www.sustain.ubc.ca/seeds-library](http://www.sustain.ubc.ca/seeds-library)
LCA data shows us the link between decisions, products, processes and the environment.
CONCLUSIONS

“You can’t manage what you can’t measure”
“Call yourself green? Prove it.”
RECOMMENDATIONS

- LCA is ideally applied during the design process
  - Cost Effective
  - Change the way we make building design decisions

- An LCA is only as good as the methods used and databases available
  - Still plenty of chances for uncertainty to accumulate
  - Improve the methodology
  - Improve the databases

- Provide the tools for specialists to contribute

- Create online tool to more easily share reports and results
Globally, LCA is currently being integrated at all scales of sustainable development guidelines.

The most recent developments include:

- LEED for New Construction 2009: Innovation & Design Credit 1
- LEED 2012 Pilot
- ASHRAE 189.1
- International Green Construction Code (IgCC)
- ISO 21931-1: Sustainability in Building Construction
THANK YOU!

Kasian Architects, Cannon Design, City of Richmond

Dr. Paul McFarlane, Department of Civil Engineering, UBC SEEDS Program,

UBC Sustainability Office, UBC Records Department
THANK YOU!

• Introduction
  • What is LCA?
  • How can it help?
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• Conclusion
  • London 2012
  • Recommendations
  • Where do we go from here?

QUESTIONS??

Where do you see LCA in the future?

Suggestions?