River Team 2012

Nick
Yao
Mike
Tom
Maria
Nicholas

E
E
CM
E
LCFM
A
Owners

Weimar, Germany

Bauhaus- University Weimar

New campus building

David

Forest
Architecture

Team Member

Nicholas

architecture  structure  construction  mep  life cycle financial management
Site Conditions

Weimar, Germany
Site Conditions

Weimar, Germany
Site Conditions

Sun path on site
### Site conditions

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<th>Average snow days</th>
<th>Average Fog days</th>
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Challenges

Challenges and goals set for the group

Flooding

Net-energy zero

Trees on site
Green box
Bio Mimicry

Moss - Biowall
Big idea

It all started with an idea

Sloped rooms  Combine  More space  Green box
Iterations

Evolution of the design

From Analog to digital

Allocating the spaces

Working with the cantilever

Expensive biowall/wasted spaces

AE
Iteration 1

AE
Iteration 2

ACLCFM
Iteration 3
Green Box

3D overview + Site orientation
2nd floor

Instructional Labs: 184 m²
Small Classrooms: 187 m²
Large Classrooms: 148 m²
Department Chair: 27 m²
Senior Assistant: 27 m²
MEP Room: 30 m²

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3rd floor

Architecture
Structure
Construction
Mep
Life cycle financial management

Faculty offices 334 m2
Faculty lounge 94 m2
Assistents 27 m2

36m
30m

N
Section A

- Architecture
- Structure
- Construction
- Life cycle financial management
Section B

architecture
structure
Construction
Life cycle financial management
Green Box- Structural

Structural Options:
• Concrete
• Steel
### Loading

**Standards:**
International Building Code

Using Load and Resistance Factor Design (LRFD)

- **LC1**: 1.4 \( D \)
- **LC2**: 1.2 \( D + 1.6 \ L + 0.5L_r \)
- **LC3**: 1.2 \( D + 1.6L_r + 1.0 \ L + .8W \)

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Design Challenges

Two Main Challenges:

• Clear space of 16.3m (53ft) x 17.3m (57ft) in the auditorium on the first floor

• 6m (20ft) cantilever on the second and third floor on the east side
Green Box- Concrete
Structural Plan and Grid

Two sub structures:
- Green Box
- Periphery

Footprint

Green Box

Shear Walls

Large classrooms

4 @ 4.3m

4 @ 3.85m
Structural Elevation

East Elevation

Section Through the Auditorium
Green Box Detail

Green Box Structure Profile:

- Columns with capitals and drop panels
- 8” two way flat slab with beams
- 4 shear walls
Periphery Detail

Periphery Structure Profile:

- Columns with capitals and drop panels
- 6” two way flat slab
- 5 shear walls
- Arched beams supporting the cantilever
Green Box - Steel

- Architecture
- Structure
- Construction
- MEP
- Life Cycle Financial Management
Solutions - Auditorium

Need to reduce loading on top of the auditorium.

Solution 1-
- Remove wasted floor space
- Removes 2 columns and allows for solution 2

Solution 2-
- Truss to carry more load
- Spans 17.3 m
W 24 x 104

Girder loading
P = 107 kN
P = 120 kN

Girder Moment
Mu = 528 kN-m

Girder Shear
V = 186 kN

Max Deflection:
\[ \Delta = 0.0043 \text{ m (1.7")} \]
Solutions - Cantilever

- Large girders.

- Increase beam size on third floor and roof

- Add extra columns to reduce Tributary Area
SAP Analysis

Deflection

= 0.015 m (.59")
Level 1 Floor Plan

Columns
W 10 x 33
W12 x 40
Level 2 Floor Plan

- W14 x 109
- W12 x 35
- W24 x 104
- W30 x 148

Columns
- W 10 x 33
- W 12 x 40
Level 3 Floor Plan

- **W14 x 109**
- **W12 x 35**
- **Truss**

**Columns**
- W 10 x 33
- W 12 x 40
Floor to Floor Height

Offices

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Helio
Bio Mimicry

Heliotropism is the diurnal motion of plant parts (flowers or leaves) in response to the direction of the sun.
Big idea

It all started with an idea

- Sun Path on site
- Embrace space
- Roof shape

Subtract

Equals

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Iterations

Evolution of the design
3d Overview
Atrium
2nd floor

- Large Classrooms: 150m²
- Small Classrooms: 180m²
- Faculty offices: 321m²
- Faculty lounge: 66m²

Architecture
Structure
Construction
Mep
Life cycle financial management
3rd floor

Classrooms

Small Classrooms

Seminar room

Administration

MEP room

Storage

Classrooms

Small Classrooms

Seminar room

Administrative

MEP room

Storage

180m²

75m²

90m²

65m²

95m²

18m

12m
North Facade

Classrooms

architecture
structure
construction
mep
life cycle financial management
Section A
Section B

architecture
structure
construction
mep
life cycle financial management
Heliotropism – Structural

Structural Options:
- Steel
- Timber
Design Challenges

- 1st Floor Auditorium spans
- Curved, cantilevered green roof
- Slanted profile

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Heliotropism – Steel Structure

- 54.9 m (180 ft)
- 45.7 m (150 ft)
- 9.14 m (30 ft)
Solutions

- Auditorium spans
- Curved, cantilevered roof
- Slanted profile

Use shape to advantage with stepped columns

*3rd Floor spans ½ the length of the auditorium

15.9m (52 ft)
• Auditorium spans

• Curved, cantilevered roof

• Slanted profile

Solutions

• Cut building into radial sections
• Use slanted shape for lateral stiffness

18.9m (62 ft)
Gravity and Lateral System

Beams
- W24x94
- W12x35
- W12x50

Columns
- W10x33

Roof Truss
- HSS6x6x0.5

Braced Frame

RC Shear Wall
Gravity and Lateral System

Beams
- W24x94
- W12x35
- W12x50

Columns
- W10x33

Roof Truss
- HSS6x6x0.5

Braced Frame

RC Shear Wall
Floor Sandwich

Typical Cross-section

- 0.46m
- 3.04m
- 2.6m (8.5ft)

Offices
Design Inspiration - Timber
Structural Rendering - Timber
Structural rendering Timber
Grid Layout

**Transversal Grid lines:**
- 5.2m (17ft) span at the auditorium
- 11 to 15 degrees rotational span at the curved pavilion
- Transversal grid lines also define the diaphragm

**Longitudinal grid lines:**
- 6m (20ft) span
- follow the shape of the building
Sections And Critical Loadings

Auditorium Section and Load Profile

Curved Pavilion Section and Load Profile
Auditorium Framing Detail

Slanted columns form a stable trapezoidal geometry.

Floor trusses hang the auditorium ceiling.

6.0m (20ft)

Clear space for the auditorium on the first floor.
Curved Pavilion Framing Detail

Slanted columns form the triangular frame geometry

Slanted columns bear the gravity load and resist the lateral load created by the slanted roof

Wood–cable space trusses support the slanted roof and maintain the geometry

6.0m (20ft)
Design and Considerations

Design:

✈ Used glued laminated (glulam) timber as structural members

✈ Sizes

Further Challenges:

✈ Connections

✈ Consider torsion

✈ Need further consideration on the structure supporting the auditorium
MEP
Heating/Cooling

Climate Data

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**MEP**

**Approach**

- Cogeneration
  - Fuel Cells
  - Solar Cogeneration
- Dual Air Handling Units
  - Auditorium
  - Ventilation
- Distribution
  - Forced air (Aud.)
  - Radiant heat flooring

*Images of a fuel cell energy system and solar panels.*

**Energy**

- Natural Gas
- Solar Cogen

**Hot Water**

- Solar

**Waste Heat**

- Energy

**Waste Heat**

- Forced air and radiant heat flooring
BIOWALL

1st Floor Hallway

2nd Floor Hallway

Auditorium

Plants

Soil-less medium

To AHU

Wall

Air Plenum

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Net Zero Building

Feasibility Check

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<th>Solar Energy Generation Potential (Weimar)</th>
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**Target Consumption**

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**System Size**: 101kW

**NET ZERO TARGET**

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<td>German Average</td>
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price per kw system
Solar Cogeneration

Efficiency Gains

PHOTOVOLTAICS

PV 18%
Lost 82%

SOLAR COGENERATION

Lost 25%
PV 15%
Waste Heat Recovery 60%
Solar Cogeneration

Efficiency Gains

PHOTOVOLTAICS

- PV: 18%
- Lost: 82%

SOLAR COGENERATION

- PV: 15%
- Lost: 25%
- Waste Heat Recovery: 60%

5 x Efficiency

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Solar Cogeneration

Efficiency Gains

PHOTOVOLTAICS

10,000 SF

SOLAR COGENERATION

2,600 SF
Solar Cogeneration

Efficiency Gains

PHOTOVOLTAICS

2,000 SF

SOLAR COGENERATION

2,000 SF

2,600 SF
Solar Tracking
Solar Tracking
Solar Tracking
Solar Tracking

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Solar Tracking
Solar Tracking
Solar Tracking
Ventilation

Schematic

- Relief Air
- Biowall
- AHU 1
  - Faculty Offices (20)
  - Department Chair’s Office
  - Senior Admin Office
  - Admin Assistants (20)
  - Faculty Lounge
- AHU 2
  - ERV
  - Outdoor Air
  - Auditorium
- Large Classrooms (2)
- Small Classrooms (4)
- Seminar Rooms (4)
- Computer Labs (2)
- Technical Support
- Student Offices (20)
- Large Classrooms (2)
- Small Classrooms (4)
- Seminar Rooms (4)
- Computer Labs (2)
- Technical Support
Heating/Cooling

Schematic

- **Power Generation**
  - Fuel Cells
  - Solar Co-gen

- **Energy Sources**
  - Natural gas
  - Municipal water
  - Domestic hot water
  - Snowmelt

- **Energy Storage**
  - HW Storage Tank

- **Energy Distribution**
  - Vertical Ground Loop
  - GSHP
  - Radiant heating loop

- **Heating Zones**
  - Zone 1
  - Zone 2
  - Zone 3
  - Zone ...

- **Additional Elements**
  - Architecture
  - Structure
  - Construction
  - MEP
  - Life cycle financial management
Heating/Cooling

Schematic – Solar CoGen

Power Generation

Solar Co-gen

HW Storage Tank

GSHP

Vertical Ground Loop

Radiant heating loop

Zone 1

Zone 2

Zone 3

Zone ...

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Heating/Cooling

Schematic – Fuel Cell

- Natural gas
- Municipal water
- Snowmelt
- Domestic hot water

Fuel Cells → Power Generation

HW Storage Tank

Electricity

Domestic hot water
Construction
Logistics Plan

Site Access Limitations

- Streets
  - Narrow
  - Unusable
  - One way
Prefabrication

Façade

- SIPS
- Curtainwall
- Orientation
Prefabrication

Structural Steel

- Prefabbed onsite
- MEP chaseway
- 50% schedule reduction
Local Materials

- Glassolutions Saint-Gobain: Glazing
- Eisen-Fischer: Steel Fabricator
- Thomas Transportbeton: Concrete
- Loxam Rental: Equipment
- Schott Solar: Photovoltaics

Keywords:
- Architecture
- Structure
- Construction
- MEP
- Life cycle financial management
Target Costing

Determining Value Needed

Avg. Baseline Est. $5,898,878
Budget $7,878,874
Value Needed $1,979,996
### Owner Targets

Please rate each category as to the importance of spending money on that item. Note that some categories fall under several different areas.

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<td>0</td>
<td>0</td>
</tr>
<tr>
<td>C. Interiors</td>
<td>Interior Finishes</td>
<td>0</td>
<td>0</td>
<td>0</td>
</tr>
<tr>
<td>C. Interiors</td>
<td>Interior Lighting</td>
<td>0</td>
<td>0</td>
<td>0</td>
</tr>
<tr>
<td>D. Services</td>
<td>Thermal Comfort</td>
<td>0</td>
<td>0</td>
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<tr>
<td>Faculty Offices</td>
<td></td>
<td></td>
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</tr>
<tr>
<td>B. Shell</td>
<td>Windows</td>
<td>0</td>
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</tr>
<tr>
<td>C. Interiors</td>
<td>Interior Doors</td>
<td>0</td>
<td>0</td>
<td>0</td>
</tr>
<tr>
<td>C. Interiors</td>
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<tr>
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<tr>
<td>D. Services</td>
<td>Thermal Comfort</td>
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<tr>
<td>Public Spaces</td>
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<tr>
<td>B. Shell</td>
<td>Windows</td>
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<tr>
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<tr>
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<tr>
<td>C. Interiors</td>
<td>Interior Lighting</td>
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<td>0</td>
<td>0</td>
</tr>
<tr>
<td>D. Services</td>
<td>Thermal Comfort</td>
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<td>0</td>
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<tr>
<td>Student Offices</td>
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<tr>
<td>B. Shell</td>
<td>Windows</td>
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<tr>
<td>C. Interiors</td>
<td>Interior Doors</td>
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<tr>
<td>C. Interiors</td>
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<tr>
<td>C. Interiors</td>
<td>Interior Lighting</td>
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</tr>
<tr>
<td>D. Services</td>
<td>Thermal Comfort</td>
<td>0</td>
<td>0</td>
<td>0</td>
</tr>
</tbody>
</table>
Target Costing

Developing Target Costs

- **Building Shell:** $389,287.93
- **Interiors:** $254,922.14
- **Noise Protection:** $41,428.30
- **Flood Protection:** $124,284.90
- **Services:** $1,161,511.45

**Cost Breakdown:**

- Architecture
- Structure
- Construction
- MEP
- Life Cycle Financial Management
Target Costing

Developing Target Costs

A. Substructure

B. Shell

C. Interiors

D. Services

Construction Mitigation

Baseline

Added Value

architecture  structure  construction  mep  life cycle financial management
# Target Costing

## Developing Target Costs

<table>
<thead>
<tr>
<th>Material</th>
<th>Estimate</th>
<th>Delta</th>
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<tbody>
<tr>
<td><strong>Target</strong></td>
<td>$7,880,000</td>
<td>$0</td>
</tr>
<tr>
<td>Green Box Concrete</td>
<td>$7,792,000</td>
<td>-$88,000</td>
</tr>
<tr>
<td>Green Box Steel</td>
<td>$7,933,000</td>
<td>$53,000</td>
</tr>
<tr>
<td>Helio Steel</td>
<td>$7,598,000</td>
<td>-$282,000</td>
</tr>
<tr>
<td>Helio Timber</td>
<td>$7,840,000</td>
<td>-$40,000</td>
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</tbody>
</table>
Target Costing

Final Estimates

- **helioTimber**
- **helioSteel**
- **SteelBox**
- **ConcreteBox**
- **Target**

- A. Substructure
- B. Shell
- C. Interiors
- D. Services
- E. Speciality Construction
- F. Building Sitework

<table>
<thead>
<tr>
<th>Architecture</th>
<th>Structure</th>
<th>Construction</th>
<th>MEP</th>
<th>Life Cycle Financial Management</th>
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</thead>
<tbody>
<tr>
<td>$0</td>
<td>$1,000,000</td>
<td>$2,000,000</td>
<td>$3,000,000</td>
<td>$4,000,000</td>
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## Construction

### Schedule – Green Box Steel

<table>
<thead>
<tr>
<th>Year</th>
<th>Quarter 2</th>
<th>Quarter 3</th>
<th>Quarter 4</th>
<th>Quarter 1</th>
<th>Quarter 2</th>
<th>Quarter 3</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>April</td>
<td>May</td>
<td>June</td>
<td>July</td>
<td>Aug.</td>
<td>Sep.</td>
</tr>
</tbody>
</table>

- **Tree Transplanting**
- **Levee**
- **Earthwork**
- **Mobilization**
- **Foundation**
- **Structure**
- **Basement**
- **1st Floor**
- **2nd Floor**
- **Services**
- **Façade**

- **Architecture**
- **Structure**
- **Construction**
- **MEP**
- **Life Cycle Financial Management**
## Construction

### Schedule – Green Box Concrete

<table>
<thead>
<tr>
<th>Tree Transplanting</th>
<th>Levee</th>
<th>Earthwork</th>
<th>Mobilization</th>
<th>Foundation</th>
<th>Building Structure</th>
<th>1st Floor</th>
<th>2nd Floor</th>
<th>Services</th>
<th>Auditorium</th>
<th>Structure</th>
<th>Auditorium Build out</th>
<th>Façade</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td></td>
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<td></td>
</tr>
</tbody>
</table>

<table>
<thead>
<tr>
<th>Quarter 2</th>
<th>Quarter 3</th>
<th>Quarter 4</th>
<th>Quarter 1</th>
<th>Quarter 2</th>
<th>Quarter 3</th>
</tr>
</thead>
<tbody>
<tr>
<td>April</td>
<td>May</td>
<td>June</td>
<td>July</td>
<td>Aug.</td>
<td>Sep.</td>
</tr>
<tr>
<td>April</td>
<td>May</td>
<td>June</td>
<td>July</td>
<td>Aug.</td>
<td>Sep.</td>
</tr>
</tbody>
</table>

- **Architecture**
- **Structure**
- **Construction**
- **Mep**
- **Lifecycle Financial Management**
# Construction

**Schedule – Helio Steel**

<table>
<thead>
<tr>
<th></th>
<th>Quarter 2</th>
<th>Quarter 3</th>
<th>Quarter 4</th>
<th>Quarter 1</th>
<th>Quarter 2</th>
<th>Quarter 3</th>
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</thead>
<tbody>
<tr>
<td></td>
<td>April</td>
<td>May</td>
<td>June</td>
<td>July</td>
<td>Aug.</td>
<td>Sep.</td>
</tr>
</tbody>
</table>

- **Tree Transplanting**
- **Levee**
- **Earthwork**
- **Mobilization**
- **Foundation**
- **Structure**
- **1st Floor**
- **2nd Floor**
- **3rd Floor**
- **Services**
- **Façade**

*Note: The diagram shows the progress of various construction tasks across different quarters.*

*Architecture, Structure, Construction, MEP, Life Cycle Financial Management*
# Construction

## Schedule – Helio Timber

<table>
<thead>
<tr>
<th></th>
<th>Quarter 2</th>
<th>Quarter 3</th>
<th>Quarter 4</th>
<th>Quarter 1</th>
<th>Quarter 2</th>
<th>Quarter 3</th>
</tr>
</thead>
<tbody>
<tr>
<td>Tree Transplanting</td>
<td></td>
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<td></td>
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<td></td>
</tr>
<tr>
<td>Levee</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Earthwork</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Mobilization</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Foundation</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Structure</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>1&lt;sup&gt;st&lt;/sup&gt; Floor</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>2&lt;sup&gt;nd&lt;/sup&gt; Floor</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>3&lt;sup&gt;rd&lt;/sup&gt; Floor</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Services</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Façade</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
</tbody>
</table>

- **Architecture**: April, May, June
- **Construction**: July, Aug., Sep.
- **Foundation**: April, May, June
- **Levee**: July
- **Earthwork**: Aug.
- **Services**: Sep., Oct., Nov., Dec.
- **1<sup>st</sup> Floor**: May, June
- **2<sup>nd</sup> Floor**: July, Aug.
- **3<sup>rd</sup> Floor**: Sep., Oct.
Construction Visualization

Excavation Phase
Construction Visualization

Foundation Phase
Construction Visualization

Prefabricated Structure Phase
Construction Visualization

Prefabricated Cladding Phase
Life Cycle Financial Management

Team Member

Maria

Life Cycle Cost

- Construction Cost: 39%
- Operation and Maintenance Financing: 61%

architecture  structure  construction  mep

life cycle financial management  102
# Risk Identification

Identification, allocation, evaluation of risks

<table>
<thead>
<tr>
<th>Risk name</th>
<th>Description</th>
<th>Consequences</th>
<th>Risk Allocation</th>
<th>Responsibility</th>
</tr>
</thead>
<tbody>
<tr>
<td>Planning phase</td>
<td></td>
<td></td>
<td>X</td>
<td>A, E</td>
</tr>
<tr>
<td>1  wrong sizing</td>
<td>wrong sizing (windows, doors, columns...)</td>
<td>problems to fulfill the time schedule -&gt; increasing costs</td>
<td>X</td>
<td></td>
</tr>
<tr>
<td>2  requirement risk</td>
<td>incorrectly predicted user requirements (quantity, quality, functionality...)</td>
<td>additional costs, possibly time delay -&gt; increasing costs</td>
<td></td>
<td>X</td>
</tr>
<tr>
<td>3  Financing risk</td>
<td>capital for intermediate or long-term financing cannot/not on the planned terms be applied</td>
<td>Risk for whole project, scheduling risk</td>
<td>X</td>
<td>X</td>
</tr>
<tr>
<td>4  permission risk</td>
<td>permission takes longer than expected</td>
<td>problems to fulfill the time schedule -&gt; increasing costs</td>
<td>X</td>
<td></td>
</tr>
<tr>
<td>5  legal risk and changing of standards</td>
<td>revise planning/calculations</td>
<td>problems to fulfill the time schedule -&gt; increasing costs</td>
<td></td>
<td>X</td>
</tr>
<tr>
<td>6  wrong cost estimation</td>
<td>uncertainty of future prices</td>
<td>budget explosion</td>
<td>X</td>
<td></td>
</tr>
<tr>
<td>7  date delay</td>
<td>bad schedule for hand-ins of plans</td>
<td>time delay, more costs</td>
<td>X, X</td>
<td></td>
</tr>
</tbody>
</table>

## Risk Management

<table>
<thead>
<tr>
<th>Risk Management</th>
<th>risk probability</th>
<th>damage</th>
</tr>
</thead>
<tbody>
<tr>
<td>good communication with engineers, very careful planning</td>
<td>2</td>
<td>3</td>
</tr>
<tr>
<td>requirements fixed in contract, good documentation, owner integration</td>
<td>1</td>
<td>2</td>
</tr>
<tr>
<td>detailed finance structure, good documentation</td>
<td>1</td>
<td>4</td>
</tr>
<tr>
<td>good communication within team, go for partial permissions, stay in contact with authorities</td>
<td>2</td>
<td>2</td>
</tr>
<tr>
<td>good documentation, forecasting</td>
<td>1</td>
<td>2</td>
</tr>
<tr>
<td>close look at past price development and current trends, security deposit</td>
<td>2</td>
<td>2</td>
</tr>
<tr>
<td>updating on dead lines, restrictions for late entry</td>
<td>1</td>
<td>2</td>
</tr>
</tbody>
</table>
Risk Identification

Major risk aspects

![Risk Identification Diagram](image)
Risk Treatment

Major risk aspects

Wrong sizing risk (planning):
- communication and collaboration

Climate risk (construction):
- Buffer in schedule
- schedule for bad weather

Maintenance risk (O&M):
- High quality equipment/materials
- maintenance plan
Risk Treatment

Flooding Risk

- temporary levee construction
- storable
- small modular components
- Cost 253.000€
- risk cost 360.000 €
## Operation and Maintenance

Comparison of monthly Operation and Maintenance cost

<table>
<thead>
<tr>
<th>Per month</th>
<th>Green Box- Steel</th>
<th>Green Box- Concrete</th>
<th>Heliotropism-steel</th>
<th>Heliotropism- Wood</th>
</tr>
</thead>
<tbody>
<tr>
<td>cleaning</td>
<td>23.179 €</td>
<td>23.293 €</td>
<td>25.468 €</td>
<td>27.471 €</td>
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<tr>
<td>energy</td>
<td>0 €</td>
<td>0 €</td>
<td>0 €</td>
<td>0 €</td>
</tr>
<tr>
<td>other supplies</td>
<td>24.270 €</td>
<td>23.698 €</td>
<td>27.132 €</td>
<td>29.421 €</td>
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<tr>
<td>Operation</td>
<td>47.449 €</td>
<td>46.991 €</td>
<td>52.600 €</td>
<td>56.892 €</td>
</tr>
<tr>
<td>Maintenance</td>
<td>42.106 €</td>
<td>40.676 €</td>
<td>49.424 €</td>
<td>54.575 €</td>
</tr>
<tr>
<td>Replacement</td>
<td>94.914 €</td>
<td>93.714 €</td>
<td>104.752 €</td>
<td>103.132 €</td>
</tr>
<tr>
<td>Operation &amp; Maintenance</td>
<td>185.000€</td>
<td>182.000€</td>
<td>207.000€</td>
<td>215.000€</td>
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</tbody>
</table>
Life Cycle Cost

Comparison of Life Cycle Costs over 25 years

<table>
<thead>
<tr>
<th></th>
<th>Green Box- Steel</th>
<th>Green Box- Concrete</th>
<th>Heliotropism-steel</th>
<th>Heliotropism- Wood</th>
</tr>
</thead>
<tbody>
<tr>
<td>Construction cost</td>
<td>6.364.000 €</td>
<td>6.278.000 €</td>
<td>6.413.000 €</td>
<td>6.054.000 €</td>
</tr>
<tr>
<td>O &amp; M cost</td>
<td>5.187.000 €</td>
<td>5.097.000 €</td>
<td>5.825.000 €</td>
<td>6.082.000 €</td>
</tr>
<tr>
<td>Financing cost</td>
<td>4.617.000 €</td>
<td>4.554.000 €</td>
<td>4.653.000 €</td>
<td>4.392.000 €</td>
</tr>
<tr>
<td>Life Cycle Cost</td>
<td>16.168.000€</td>
<td>15.929.000€</td>
<td>16.891.000€</td>
<td>16.528.000€</td>
</tr>
</tbody>
</table>

architecture, structure, construction, mep, life cycle financial management
### Rent

**Total first year rent**

<table>
<thead>
<tr>
<th></th>
<th>Green Box- Steel</th>
<th>Green Box- Concrete</th>
<th>Heliotropism-steel</th>
<th>Heliotropism- Wood</th>
</tr>
</thead>
<tbody>
<tr>
<td>rent first year</td>
<td>650.000€</td>
<td><strong>640.000€</strong></td>
<td>676.000€</td>
<td>657.000€</td>
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</tbody>
</table>
Target value in Operation & Maintenance

Minimizing the Rent

Expenses – extra income = RENT

Minimizing expenses
- construction cost
  - modular elements
- operation & maintenance
  - net zero
  - bio-wall
- financing
  - financial engineering

Maximizing income
- Café
  - size, location
- rent Auditorium
  - accessibility
LEED Evaluation

Gold and aiming for platinum

LEED Gold (71 points)

Innovation points:
- net –zero
- design of biowall
- 95% construction waste diversion

Aiming Platinum:
- storm water design
- water use reduction
- landscaping
- Measurement & Verification plans
Team Process

technologies

announcements

Conversation

Regular Team meetings

File sharing

architecture
structure
construction
mep
life cycle financial management
Team process

Meeting organization

Meeting agenda

<table>
<thead>
<tr>
<th>Meeting Date</th>
<th>Facilitator</th>
<th>Recorder</th>
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<tbody>
<tr>
<td>1/22/2012</td>
<td>Mike</td>
<td>Nick</td>
</tr>
<tr>
<td>1/29/2012</td>
<td>Maria</td>
<td>Yao</td>
</tr>
<tr>
<td>2/5/2012</td>
<td>Nick</td>
<td>Tom</td>
</tr>
<tr>
<td>2/12/2012</td>
<td>Yao</td>
<td>Nicholas</td>
</tr>
<tr>
<td>2/19/2012</td>
<td>Tom</td>
<td>Mike</td>
</tr>
<tr>
<td>2/26/2012</td>
<td>Nicholas</td>
<td>Maria</td>
</tr>
<tr>
<td>3/4/2012</td>
<td>Mike</td>
<td>Nick</td>
</tr>
<tr>
<td>3/11/2012</td>
<td>Maria</td>
<td>Yao</td>
</tr>
</tbody>
</table>

Weekly role rotation

real time Meeting minutes

Setting new tasks
Team process

Meeting schedules

- **Weekly team meeting**
- **Weekly sub-meeting**
- **Special purpose sub-meeting**
- **Daily stand-up meeting**

Keywords:
- architecture
- structure
- construction
- mep
- life cycle financial management
Maximizing the Triple Bottom Line

Decision Matrix

<table>
<thead>
<tr>
<th>GOALS</th>
<th>SUBGOALS</th>
<th>ASPECTS</th>
<th>SUBASPECTS</th>
<th>STEEL</th>
<th>CONCRETE</th>
<th>STEEL</th>
<th>WOOD</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td></td>
<td></td>
<td>33.00%</td>
<td>63.7</td>
<td>63.5</td>
<td>52.7</td>
<td>53.2</td>
</tr>
<tr>
<td>Economical</td>
<td>NFA/GFA</td>
<td>max. ass. Area</td>
<td>20.00%</td>
<td>76</td>
<td>76</td>
<td>60</td>
<td>55</td>
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<tr>
<td></td>
<td></td>
<td>efficient organization</td>
<td>30.00%</td>
<td>90</td>
<td>80</td>
<td>50</td>
<td>40</td>
</tr>
<tr>
<td></td>
<td></td>
<td>Utilization of roof area</td>
<td>40.00%</td>
<td>70</td>
<td>70</td>
<td>70</td>
<td>70</td>
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<tr>
<td></td>
<td>Structure performance</td>
<td>Regular grid</td>
<td>10.00%</td>
<td>30</td>
<td>30</td>
<td>70</td>
<td>70</td>
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<tr>
<td></td>
<td></td>
<td>efficient structure</td>
<td>15.00%</td>
<td>72.5</td>
<td>72.5</td>
<td>50</td>
<td>57.5</td>
</tr>
<tr>
<td></td>
<td></td>
<td>Complexity of structure</td>
<td>50.00%</td>
<td>90</td>
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Maximizing the Triple Bottom Line

Identification, allocation, evaluation of risks
And the winner is....

Heliotropism timber construction
Thank you

 Owners: Forest and Dave
ARUP: Kyle and Afaan
University of Wisconsin: John Nelson
GPLA: Greg Luth
Degenkolb: Erik Kneer
DPR: Dan Gonzales
capgemini: Mathias Ehrlich
Bauhaus-University Weimar: Björn Wündsch

QUESTIONS ???