Winter Presentation
Development Concept Proposal
AEC Global Teamwork
15 March 2019
Project and Owner teams

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USA
Content

General Information
   - Concept Sprout

Structural Engineering

Architecture

MEP
   - Concept Duality

Architecture

Structural Engineering

MEP

Construction Management

LCFM

Legend

T Team
A Architecture
S Structural Engineering
M MEP
C Construction Management
L LCFM
S Sustainability Challenge
P Prefabrication Challenge
I IT challenge
Site Location

The building plot lies in a UNESCO World Heritage area between the historical city center and the bank of River Ilm in Weimar.
Site Opportunities and Challenges

The unique location pose flood hazard and logistics challenges

<table>
<thead>
<tr>
<th>Opportunities</th>
<th>Challenges</th>
</tr>
</thead>
<tbody>
<tr>
<td>Rich cultural heritage</td>
<td>Flooding of River Ilm</td>
</tr>
<tr>
<td>Lush natural environment</td>
<td>Limited transportation capabilities</td>
</tr>
<tr>
<td></td>
<td>Protection of existing environment</td>
</tr>
</tbody>
</table>

UNESCO World Heritage Protection
Flood Analysis

Flooding is a main hazard of the building site, which needs to be taken care of during design

Flood recurrences

100 year

200 year

Increased costs
– Damages to equipment
– Delay in schedule
– Damage building components

Reduced safety
– Personal injury
– Erosion of soil
– Structural failure

Environmental damage
– Risk of river pollution

Source:
Thuringian State Office for the Environment, Mining and Nature Conservation - Flood Risk Management service
Flood Protection

As flooding risk has a high impact the protection should be addressed on multiple levels

**Prevention**

- **Ban the use of water sensitive materials on the ground floor**
  - to reduce potential damage

- **MEP room isolated from flood area**
  - to ensure equipment protection

**Emergency**

- **Off-site warehouse**
  - to reduce risk of materials damage

- **Mobile water barrier**
  - to hold 80 cm extra water table

- **Live contact with authorities**
  - to be able to forecast and prepare for flooding

- **Emergency Operation Plan**
  - to ensure material and personal safety
Environmental data

Wind, precipitation, humidity, sunlight conditions

Average relative humidity: 78%
- December is the most humid
- May is the least humid.

Average annual dry bulb temperature:
- max 11.0° C (51.8° F)
- min 3.0° C (37.4° F)

Base Temperature: 65°F (18°C):
- HDD65: 6276
- CDD65: 630
Environmental data

Shading

At 9am, noon and 3pm on spring equinox, summer solstice, fall equinox and winter solstice.
Thermal Comfort Strategies

Psychrometric Chart

DESIGN STRATEGIES: JANUARY through DECEMBER

- Comfort (542 hrs)
- Sun Shading of Windows (0 hrs)
- High Thermal Mass (0 hrs)
- High Thermal Mass Night Flushed (0 hrs)
- Direct Evaporative Cooling (0 hrs)
- Two-Stage Evaporative Cooling (0 hrs)
- Natural Ventilation Cooling (0 hrs)
- Fan-Forced Ventilation Cooling (0 hrs)

- Internal Heat Gain (2407 hrs)
- Passive Solar Direct Gain Low Mass (0 hrs)
- Passive Solar Direct Gain High Mass (0 hrs)
- Wind Protection of Outdoor Spaces (0 hrs)
- Humidification Only (0 hrs)
- Dehumidification Only (0 hrs)
- Cooling, add Dehumidification if needed (0 hrs)

62.2% Cooling, add Humidification if needed (5450 hrs)

95.9% Comfortable Hours using Selected Strategies
(8399 out of 8760 hrs)
Structural Analysis
Land and soil condition

Gravity

Snow : 0.85 kN/m²
Office : 2.0 kN/m²
Auditorium : 4.0 kN/m²
Large Classrooms : 4.0 kN/m²
Large Corridor : 5.0 kN/m²

Lateral

Wind Load : -0.78 - 0.455 kN/m²

Design based on Eurocode 0 - 8
(DIN EN 1990 - DIN EN 1998)
Structural Analysis
Foundation options

Spread Footing

<table>
<thead>
<tr>
<th>Layer</th>
<th>Soil Type</th>
<th>Bot Depth [m]</th>
<th>Capacity [kN/m²]</th>
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<tbody>
<tr>
<td>1</td>
<td>Mould Top Soil</td>
<td>-0.508</td>
<td>-</td>
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<tr>
<td>2</td>
<td>Younger Rimstone</td>
<td>-1.143</td>
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<tr>
<td>3</td>
<td>Keuper</td>
<td>-1.524</td>
<td>-</td>
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<tr>
<td>4</td>
<td>Medium Shell Limestone</td>
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<tr>
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<td>Medium Shell Limestone</td>
<td></td>
<td>383.0</td>
</tr>
</tbody>
</table>

Water Table: -1.219

Micropiles

![Typical Micro-pile Foundation Diagram]
Concept: Sprout
Footprint Location

Site Location

Footprint location

Building plot

People flow

Footprint
Big Idea - Sprout
Our building serves as a resource to students to grow just as the water, soil and air for a sprout

- strength - to keep the leaves
- development – adapt to environment
- spirit of discovery – move towards light
- development into a healthy, strong plant
Big Idea - Floor Distribution
Sprout - how the big idea influence architecture

Idea grew up from one module to the whole building

Students and faculty modules in the top of a building as a leaves

Collaboration spaces in the middle as a connection of a branches

Core functions on the bottom as a stump of a tree
Sprout concept
Drone’s view from park
Sprout concept
Drone’s view from a bridge
Sprout concept

View from the Ilm river to main entrance
Sprout concept
Work process

co-operation is when:

- Architect create structural system.
- Structure engineer create the architectural design.

...and that is how our collaboration began.
Structural Option Standard
First variation for structural system
Structural Option Standard
Lateral resistance system

Ground Floor

250mm Reinforced Concrete

Roof

Compression: PT Concrete Slab
Tension: steel rope on the roof (40mm)
Structural Option Standard
Floor plan - Ground level

250mm Reinforced Concrete
Reinforced Concrete 400x400
Structural Option Standard

Floor plan - First Level

truss - SHS400x16
Structural Option Standard

Floor plan - Second level

truss - SHS400x16
Structural Option Standard
Load path - Section A-A
Structural Option Standard
Load path - Section B-B
Structural Option Honeycomb
Second variation for structural system
Structural Option Honeycomb

Lateral resistance system

Ground Floor

Roof

250mm Reinforced Concrete

Compression: PT Concrete Slab
Tension: steel rope on the roof (40mm)
Structural Option Honeycomb
Support structure – Ground Floor

Reinforced Concrete 400x400
Structural Option Honeycomb
Lateral resistance system – First Floor
Structural Option Honeycomb
Lateral resistance system – Second Floor

truss - SHS400x16
Structural Option Honeycomb
Load path – Section A-A

Lateral

Gravity
Structural Option Honeycomb
Load path – Section B-B

- **Lateral**

- **Gravity**
Structural Options
Collaboration between ARCH - SE
Evolution of concept Sprout
Collaboration between ARCH - SE
Evolution of concept Sprout

Collaboration between ARCH - SE - CM
Evolution of concept Sprout
Collaboration between ARCH - SE - CM - MEP

IDEA of 4 trusses + CONTAINERS BETWEEN + FLEXIBLE SPACES

6th floor → 10 columns
Arch + SE + LCFM → ARCH + SE → SIMPLIFIED GRID, lower costs → HONEYCOMB ARCH + SE

Impact to:
- more functional plans
- visual advantages
- prefabrication
- lower cost of transport
- lower costs of replacing/repairing LCFM
Evolution of concept Sprout
Collaboration between ARCH - SE - CM - MEP - LFCM

IDEA of 4 trusses

CONTAINERS BETWEEN

FLEXIBLE SPACES

G.Floor -> columns
ARCH + SE + LCFM

ARCH + SE

SIMPLE GRID
Lower costs

HONEY COMB
ARCH + SE

two symmetric cones
ARCH + SE + MEP

- more functional plan
- better shaft distribution
- strong core stability

Extra ordinary

shafts created to provide better air distribution
ARCH + MEP

containers changed into basic elements
slopes and columns - groups of elements
- Lower cost of prefabrication
- Flexibility
- Consider replacement/repairing LCFM

impact to:
- more functional plan
- visual advantages
- prefabrication
- lower cost of transport
- Lower costs of replacing/repairing LCFM

TASMCL | SPI
Sprout concept

View from the Ilm river to main entrance
Sprout
Room distribution

2nd Floor
- Offices

1st Floor
- collaboration space
- Classrooms

Ground Floor
- Public space
Sprout
Room distribution

2nd Floor
Offices

collaboration space

1st Floor
Classrooms

Ground Floor
Public space
Sprout - Growth of Youth

View to the informal interaction space from 1st floor
Sprout - Growth of Youth
Public amphitheater for open events
Second Floor

- Collaboration
- Seminar room
- Utility rooms
- Flexible offices

Park side

River side
Sprout- Flexibility

Folding walls between classrooms- adjust to users needs
Sprout concept
Section
### HVAC options

#### Classroom, office and auditorium

<table>
<thead>
<tr>
<th>Classroom, office</th>
<th>Auditorium</th>
</tr>
</thead>
<tbody>
<tr>
<td><strong>Radiant Floor</strong></td>
<td><strong>HRV + Demand Controlled Ventilation</strong></td>
</tr>
<tr>
<td><strong>Capillary Ceiling</strong></td>
<td><strong>Separate AHU</strong></td>
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#### Pro
- Prefab with slab
- Adaptive
- Fast acceleration
- No extra equipment
- Reduce heating load
- Best for cold climate
- Easier to monitor and control
- Extra equipment
- Less energy efficient

#### Con
- Longer reaction time
- Expensive to install
- Costly
- Require most maintenance
- - Extra equipment

---

**Ventilation:** Natural Ventilation controlled by CO2 sensor, supplemented with DOAS with some form of HRV  
**Heating:** Capillary wall and/or ceiling
HVAC options
Schematic drawing
MEP Room and Shafts

Roof - DOAS equipment on the rooftop
MEP Room and Shafts

MEP room on First Floor to avoid flooding
MEP Room and Shafts

Ground Floor - Smaller MEP shaft

Shasfts
MEP Room and Shafts

MEP shaft section

Separate ventilation from MEP room to auditorium
Distribution Tree

Ground Floor

Ceiling-mounted return air grill – return air through plenum
Distribution Tree
First Floor
Distribution Tree
Second Floor

Return air grill in collaboration space
Floor sandwich options

**Classroom**

Option 1: Capillary Ceiling
- Slab: ~200mm, Beam: ~450mm
- Ventilation Duct: ~350mm
- Capillary Ceiling Tube: ~OD-10mm
- Clear Space: ~3.18m

Option 2: Radiant Floor
- Beam: ~400mm, Bottom Slab: ~200mm
- Ventilation Duct: ~OD-350mm
- Radiant Floor Tube: ~OD-15mm
- Insulation: ~25mm
- Clear Space: ~3.25m
Floor sandwich options

Auditorium

- Sloped auditorium
- PT Slab: ~200mm
- Underfloor Supply Air Plenum: ~300mm
- Overhead Return Air Plenum: ~400mm
- Clear Space: ~3.1 to 7.1m
Natural Ventilation

How it works

Cross Ventilation

Opening area ≥4% of floor area

Single-sided Ventilation

T A S M C L | S P I
Operable Windows Allowing Single-sided Ventilation
Small classroom & Lab on First Floor

$$W = 5.875 \text{ mm}; \ H = 4.000 \text{ mm}$$

Small Classroom Area = 39.6$$\text{m}^2$$
Window size: 2150*1500mm = 3.225$$\text{m}^2$$
Opening% = 8.14%

Instructional Lab Area = 86.9$$\text{m}^2$$
Window size: 2150*1500mm*4 = 13.7$$\text{m}^2$$
Opening% = 15.8%
Operable Windows Allowing Single-sided Ventilation
Office on Second Floor

W=3.375mm; H=4.000mm

Office Area = 13.3m²
Window size: 2150*1500mm = 3.225m²
Opening% = 24.2%
Architectural Design Enables Natural Ventilation
Operable louver skylights

Allow major wind from SW into the building
Architectural Design Enables Natural Ventilation
Operable louver skylights

Allow major wind from SW into the building
Sustainability solutions
Natural wool insulation

- Renewable & recyclable
- Good performance
- Flame retardant & self-extinguishing
- ODP = 0, GWP = 0
- Condensation
Sustainability solutions
Orientation and angle of PV Panels/Skylights

- Annual Solar Irradiance = 1,055.53 kWh/m²
- Need about ~1,687m² PV panels to cover annual electricity
Concept
Duality
Footprint Location

Site Location

Footprint location

Building plot

People flow

Footprint
Big Idea - Duality
Our building symbolizes the transition from an old frontal education system to a dynamic collaborative future.
Big Idea - Duality
How big idea influence architectural design

TWO BUILDINGS

TWO SHAPES
SIMPLE + EXTENDED

INTERIOR
EXTERIOR

ATRIUM
CONNECT
TWO BUILDINGS

COMMUNICATION
Panorama of Weimar
Main entrance from the park
Panorama of Weimar

Entrance from the river
Big Idea Duality

Facing the water building is an arch between the park and river.
Building model
Main entrance from river
Atrium view - section A-A
Ground Floor entrance from river
First Floor entrance from the park
Interaction between ARCH - SE

Several Options for Stairs

Flow of Movement

Where can we put “Columns” and how many?
Skylight supporting system - collaboration ARCH+SE

The process of creating the support

Voronoi diagram- grid based on that will divide skylight plane for some spaces. Forces will be divided for 5 different columns.
Skylight supporting system - collaboration ARCH+SE

The process of creating the support

**Voronoi diagram** - grid based on that will divide skylight plane for some spaces. Forces will be divided for 5 different columns.

Transfer loads from skylight and other elements to the ground - choose the most optimal place on the ground for column.

**Optimisation by Galapagos** (Rhinoceros + Grasshopper) to choose the most optimal load delivery on the supporting columns.
Skylight supporting system - collaboration ARCH+SE

The process of creating the support

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**Topology optimisation** (Fusion 3D) for each column separately
Skylight supporting system - collaboration ARCH+SE

The process of creating the support

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**Topology optimisation** (Fusion 3D) for each column separately

**Prefabrication** - divide columns for the limited number of duplicate elements - columns and fasteners.
Atrium
View to the river from park side, First Floor
Section B-B

Park side

River side
Structural Option Steel
First variation for structural system
Structural Option Steel

Floor Plan: beams and columns - First Floor

Columns
- SHS 300*16

Beams
- HEM 300
- HEM 340
- HEM 320
- HEM 200
- HEM 120
- HEM 500

Walls
- concrete 300mm
- Parametric Timber
Structural Option Steel

Floor Plan: beams and columns - Second Floor

Columns
- SHS300*16

Beams
- HEM 300
- HEM 340
- HEM 320
- HEM 200
- HEM 120
- HEM 500

Walls
- concrete 300mm
- Parametric Timber
Structural Option Steel
Floor Plan: beams and columns - Roof

Columns
- SHS300*16

Beams
- HEM 300
- HEM 340
- HEM 320
- HEM 200
- HEM 120

Walls
- concrete 300mm

Other Elements
- HEM 220 Bracing
- HEM 120 Bracing
- PT Concrete 250mm
- Roof Truss
Structural Option Steel
Lateral resistance system

Walls
- concrete 300mm
Structural Option Steel
Load path - Section A-A
Structural Option Steel
Load path - Section B-B
Structural Option Steel and Timber
Second variation for structural system
Structural Option Steel and Timber
Support structure - Ground Floor

Columns
- HEM 300
- HEM 500

Beams
- HEM 300
- HEM 340

Walls
- concrete 300mm
- concrete 200mm
Structural Option Steel and Timber
Support structure - First Floor
Structural Option Steel and Timber Support structure - Second Floor

- Support system (timber 300x160/800)
- Support system (timber 200x200/2000)
- Support system (timber 400x200/2000)
- CLT 300mm
- Concrete 300mm
- Timber beam 400x200
- Timber beam 600x200
- Timber elements
- HEM 300
- HEM 340
- HEM 500
Structural Option Steel and Timber

Collaboration

- Opening and Atrium for Architect
- Openings for MEP
- Constructability for CM
Structural Option Steel and Timber
Load path - Section A-A

Lateral

Gravity
Structural Option Steel and Timber
Load path - Section B - B

Lateral

Gravity
Structural Option Steel and Timber

Load path - Section C-C

- Lateral
- Gravity
# MEP options

## Classroom, office and auditorium

### Classroom, office

<table>
<thead>
<tr>
<th>Radiant Floor</th>
<th>Capillary Ceiling</th>
<th>HRV + Demand Controlled Ventilation</th>
<th>Separate AHU, overhead conditioned air distribution system</th>
</tr>
</thead>
<tbody>
<tr>
<td><img src="image1.png" alt="Radiant Floor" /></td>
<td><img src="image2.png" alt="Capillary Ceiling" /></td>
<td><img src="image3.png" alt="HRV + Demand Controlled Ventilation" /></td>
<td><img src="image4.png" alt="Separate AHU, overhead conditioned air distribution system" /></td>
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**Pro**
- Prefab with slab
- Adaptive
- Fast acceleration

**Con**
- Longer reaction time
- Expensive to install
- No extra equipment
- Reduce heating load
- Best for cold climate
- Costly
- Require most maintenance

**Ventilation**: Natural Ventilation controlled by CO2 sensor, supplemented with DOAS with some form of HRV
**Heating**: capillary wall and/or ceiling

**Pro**
- Easier to monitor and control

**Con**
- Extra equipment
- Less energy efficient
HVAC options
Schematic drawing
MEP Room and Shafts

Roof - DOAS equipment on the rooftop
Distribution Tree
Ground Floor
Distribution Tree
First Floor
Distribution Tree
Second Floor
Floor sandwich options
Classroom

Option 1: Capillary Ceiling
- Slab: ~200mm, Beam: ~450mm
- Ventilation Duct: ~300mm
- Capillary Ceiling Tube: ~OD-10mm
- Clear Space: ~3.23m

Option 2: Radiant Floor
- Beam: ~400mm, Bottom Slab: ~200mm
- Ventilation Duct: ~OD-300mm
- Radiant Floor Tube: ~OD-15mm
- Insulation: ~25mm
- Clear Space: ~3.30m
Floor sandwich options

Auditorium

- Sloped auditorium
  - Beam depth: ~300mm
- Truss depth: ~1096mm
- Duct: ~OD-500mm
- Clear Space: ~6.6m
Natural Ventilation

Wind pressure

Small classrooms and offices under major wind pressure
Operable Windows Allowing Single-sided Ventilation
Small Classroom & Office

Single-sided ventilation

**Office:** $W = 6500\text{mm}, H = 4000\text{mm}$
- Office Area = 26$m^2$
- Window size: $915 \times 2500\text{mm} = 2.29m^2$
- Opening$\% = 8.8\%$

**Small Classroom:** $W = 6500\text{mm}, H = 4000\text{mm}$
- Small Classroom Area = 48$m^2$
- Window Area: $2 \times 915 \times 2500\text{mm} = 4.58m^2$
- Opening$\% = 9.5\%$
Operable Windows Allowing Cross Ventilation

Instruction Lab

Cross ventilation

Instructional Lab: W = 17000mm, H = 4000mm
Sustainability solutions
Carbon negative challenge

English Ivy:
- Proved by Nasa: improve IAQ
- Happier under full shade
- Wall Area = 107,000 m²
  Ivy carbon absorption: ~ 0.201ppm/sq cm
  Total potential absorption: ~ 21,507ppm
Sustainability solutions
PV Panels/Skylights

- Optimal orientation & angle

<table>
<thead>
<tr>
<th>Month</th>
<th>Jan</th>
<th>Feb</th>
<th>Mar</th>
<th>Apr</th>
<th>May</th>
<th>Jun</th>
<th>Jul</th>
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<td>2.87</td>
<td>3.71</td>
<td>4.16</td>
<td>4.13</td>
<td>4.12</td>
<td>4.06</td>
<td>3.13</td>
<td>2.24</td>
<td>1.37</td>
<td>1.16</td>
</tr>
</tbody>
</table>

- Annual Solar Irradiance = 1,055.53 kWh/m^2
- Need about ~1822m^2 PV panels to cover annual electricity
## Sustainable Target Value

### Concept Sprout

<table>
<thead>
<tr>
<th></th>
<th>Target</th>
<th>GWP (kgCO2e)</th>
<th>Energy (MJ)</th>
<th>Water (kg)</th>
<th>ODP (kgCFC11e)</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td><strong>Embodied</strong></td>
<td>5,614,551</td>
<td>152,712,505</td>
<td>198,039,452</td>
<td>(minimize)</td>
</tr>
<tr>
<td></td>
<td><strong>Used%</strong></td>
<td>1,390,925</td>
<td>17,453,489</td>
<td>13,968,846</td>
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<td></td>
<td><strong>Use Phase</strong></td>
<td>8,492,403</td>
<td>174,295,323</td>
<td>5,234,219</td>
<td>2.40E-01</td>
</tr>
<tr>
<td></td>
<td><strong>Used%</strong></td>
<td>151.3%</td>
<td>114.1%</td>
<td>2.6%</td>
<td></td>
</tr>
<tr>
<td></td>
<td><strong>Total%</strong></td>
<td>176.0%</td>
<td>125.6%</td>
<td>9.7%</td>
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</tbody>
</table>

### Honeycomb

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<tr>
<td></td>
<td><strong>Used%</strong></td>
<td>1,693,439</td>
<td>20,886,864</td>
<td>15,706,193</td>
<td>2.5E-02</td>
</tr>
<tr>
<td></td>
<td><strong>Use Phase</strong></td>
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<td>114.1%</td>
<td>2.6%</td>
<td></td>
</tr>
<tr>
<td></td>
<td><strong>Total%</strong></td>
<td>181.4%</td>
<td>127.8%</td>
<td>10.6%</td>
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Sustainable Target Value
Concept Duality

Steel

![Steel Diagram]

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<td><strong>(minimize)</strong></td>
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<tr>
<td><strong>Embodied</strong></td>
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<td>20,866,932</td>
<td>12,892,317</td>
<td>3.1E-02</td>
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<td>13.7%</td>
<td>6.5%</td>
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<tr>
<td><strong>Use Phase</strong></td>
<td>8,811,842</td>
<td>180,851,372</td>
<td>5,431,102</td>
<td>2.49E-01</td>
</tr>
<tr>
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<td>156.9%</td>
<td>118.4%</td>
<td>2.7%</td>
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</tr>
<tr>
<td><strong>Total%</strong></td>
<td>184.4%</td>
<td>132.1%</td>
<td>9.3%</td>
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</tr>
</tbody>
</table>

Steel and Timber

![Steel and Timber Diagram]

<table>
<thead>
<tr>
<th></th>
<th>GWP (kgCO2e)</th>
<th>Energy (MJ)</th>
<th>Water (kg)</th>
<th>ODP (kgCFC11e)</th>
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</thead>
<tbody>
<tr>
<td><strong>Target</strong></td>
<td>5,614,551</td>
<td>152,712,505</td>
<td>198,039,452</td>
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<tr>
<td><strong>Embodied</strong></td>
<td>1,306,681</td>
<td>18,139,998</td>
<td>11,024,379</td>
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<tr>
<td><strong>Used%</strong></td>
<td>23.3%</td>
<td>11.9%</td>
<td>5.6%</td>
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</tr>
<tr>
<td><strong>Use Phase</strong></td>
<td>8,811,842</td>
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</tr>
<tr>
<td><strong>Total%</strong></td>
<td>180.2%</td>
<td>130.3%</td>
<td>8.3%</td>
<td></td>
</tr>
</tbody>
</table>
Site Logistics
Accessibility

- Development site
- Train station
- South-West access
- North-East access

Development site

- Inner city road
- Tight intersection
- Pedestrian intersection

Minimum road width: 3.5 m
Maximum truck width: 2.6 m

Tight intersection

Accessibility
Site Logistics

Minimize environmental impact

Tree removal
- pay cost for the city
- negative environmental impact
- UNESCO compliance problems

Cost
- 5,000 EUR labor cost
- Additional municipality fines

Tree relocation
- pay for nursery service
- transplant trees to the south park area
- minimal environmental impact

Cost
- 100,000 EUR labor cost
Site Logistics

Crane selection

MDT CCS City Tower Crane

+ Lifts heavy elements
+ View to elements and site
+ Lifting speed

- Risks of damage during storms
- More exposed during flood
- 100.000 EUR in total, excluding man-hours

LTC 1050-3.1

+ Flexibility
+ 50.000 EUR in total, excluding man-hours
+ Easier set-up

- Cannot lift heavier elements
- Limited view to elements and site
- Difficult to lift elements without damaging trees
Site Logistics
Public interaction during development

Facade mock-up

Security gate, PR officer

See through fence

Project VR room
Site Logistics
Off-site warehouse and waste logistics

Construction Consolidation Center

EU initiative “SUCCESS” in cooperation with Weimar municipality.

Transportation:
- Cost
- Time
- Emission
- Traffic disruption

Reliability:
- Return on Investment
- Supply

Usable to other projects in Weimar:
- e.g. The German National Theatre reconstruction

Waste management

- Shared waste management system
- Train employees, provide incentives
- Responsible for: keep the site clean, sort the waste
- Set-up bins according to CER (Catalogo Europeo dei Rifiuti) coding
Technology on Site
Increasing safety and productivity

Site monitoring
- Drone based site monitoring
  - Safety checks
  - Project progression
  - Marketing footage

AR and VR use
- VR utilization
  - More realistic safety simulation
  - Increased participant focus
  - Simulate random scenarios
- AR utilization
  - Display safety instructions
  - Projection through surfaces
  - Showcase of project progress

Data and safety
- Accident monitoring
  - Triax Spot-R IoT device
  - Fall detection
  - 91% increased response time
- Smart sensors
  - Pillar technologies
  - Collects environmental data
  - Risk reduction to multiple parties

Autodesk Project IQ
- Machine learning image analysis
- Analyze drone footage and spot the safety risks
Site Logistics

The utilization of the grass Park area, contribute to reduce the environmental damage on the existing environment

- Minimized environmental impact
- Dedicated parking area
- Minimized flooding risk
- Free people flow around the castle
Site Logistics

The reduced building floor area leads to smaller construction site which further reduces the environmental impact

- Further minimized environmental impact
- Dedicated parking area
- Free people flow around the castle
Preliminary Construction Schedule - Sprout

The simpler structure results in faster completion

### Sprout - Standard

<table>
<thead>
<tr>
<th>ID</th>
<th>Task Name</th>
<th>Duration</th>
</tr>
</thead>
<tbody>
<tr>
<td>1</td>
<td>Key periods</td>
<td>201 dys</td>
</tr>
<tr>
<td>2</td>
<td>Academic year 2024/2025</td>
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<tr>
<td>3</td>
<td>Flooding period 2025</td>
<td>65 dys</td>
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<tr>
<td>4</td>
<td>Construction Schedule - Sprout - Standard</td>
<td>178 dys</td>
</tr>
<tr>
<td>5</td>
<td>Preliminaries</td>
<td>30 dys</td>
</tr>
<tr>
<td>6</td>
<td>Substructure</td>
<td>30 dys</td>
</tr>
<tr>
<td>7</td>
<td>Superstructure</td>
<td>25 dys</td>
</tr>
<tr>
<td>8</td>
<td>Façade</td>
<td>15 dys</td>
</tr>
<tr>
<td>9</td>
<td>Interiors</td>
<td>60 dys</td>
</tr>
<tr>
<td>10</td>
<td>MEP</td>
<td>35 dys</td>
</tr>
<tr>
<td>11</td>
<td>Testing of MEP</td>
<td>10 dys</td>
</tr>
<tr>
<td>12</td>
<td>Furnishing</td>
<td>30 dys</td>
</tr>
<tr>
<td>13</td>
<td>Partial occupancy starts</td>
<td>0 dys</td>
</tr>
<tr>
<td>14</td>
<td>Commissioning and handover</td>
<td>35 dys</td>
</tr>
<tr>
<td>15</td>
<td>Rental period</td>
<td>0 dys</td>
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</table>

### Sprout - Honeycomb

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<tr>
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<th>Duration</th>
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</thead>
<tbody>
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<td>3</td>
<td>Flooding period 2025</td>
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<tr>
<td>4</td>
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<td>Preliminaries</td>
<td>30 dys</td>
</tr>
<tr>
<td>6</td>
<td>Substructure</td>
<td>30 dys</td>
</tr>
<tr>
<td>7</td>
<td>Superstructure</td>
<td>20 dys</td>
</tr>
<tr>
<td>8</td>
<td>Façade</td>
<td>15 dys</td>
</tr>
<tr>
<td>9</td>
<td>Interiors</td>
<td>60 dys</td>
</tr>
<tr>
<td>10</td>
<td>MEP</td>
<td>35 dys</td>
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<td>11</td>
<td>Testing of MEP</td>
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<td>13</td>
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<td>14</td>
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<td>35 dys</td>
</tr>
<tr>
<td>15</td>
<td>Rental period</td>
<td>0 dys</td>
</tr>
</tbody>
</table>
Preliminary Construction Schedule - Duality

The combination of structural elements prolong the schedule

### Duality - Steel

<table>
<thead>
<tr>
<th>ID</th>
<th>Task Name</th>
<th>Duration</th>
<th>24 Aug</th>
<th>Qtr 4, 2024</th>
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<th>Qtr 2, 2025</th>
<th>Qtr 3, 2025</th>
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</tr>
<tr>
<td>7</td>
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<td>30 dys</td>
<td></td>
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<tr>
<td>8</td>
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<td>Testing of MEP</td>
<td>10 dys</td>
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<tr>
<td>15</td>
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<td>0 dys</td>
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### Duality - Steel and Timber

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<th>Qtr 2, 2025</th>
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<td>Rental period</td>
<td>0 dys</td>
<td></td>
<td></td>
<td></td>
<td></td>
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</tbody>
</table>
The target value of the project is 8,330,000 EUR which drives the cost calculation through the project.

**Target Value cluster distribution**

- Substructure: 33%
- Shell: 27%
- Interiors: 13%
- Services: 7%
- Equipment and Furnishings: 8%
- Specialty Construction: 4%
- Building Sitework: 4%
- General Conditions: 4%
- Specialty Construction: 4%

**High level cost estimate input**
- BKI Kostenplaner, budgeting software
- German standards, adjusted by locational factor
- Reference projects

**Detailed cost estimate input**
- Applied for structural system
- Quantity take-off from Revit with Dynamo Script
- Specific element selection cost from Kostplaner
Target Value Design evolution
The timeline shows how the implemented changes increased the value of the design

Sprout - Standard

Duality - Steel

Sprout - Honeycomb

Duality – Steel and Timber
Case trade-off analysis of Structural Systems
The utilization of timber elements drives up costs but reduces CO2e impact

<table>
<thead>
<tr>
<th>Material</th>
<th>Cost [EUR]</th>
<th>Prefabrication capability</th>
<th>Sustainability [kgCO2e]</th>
</tr>
</thead>
<tbody>
<tr>
<td><strong>Sprout Standard</strong></td>
<td>1.190.000</td>
<td>- One material</td>
<td>+11%</td>
</tr>
<tr>
<td></td>
<td></td>
<td>- Large elements, difficult to handle</td>
<td></td>
</tr>
<tr>
<td></td>
<td></td>
<td>- Less space occupied by elements</td>
<td></td>
</tr>
<tr>
<td><strong>Sprout Honeycomb</strong></td>
<td>1.150.000</td>
<td>- One material</td>
<td>+50%</td>
</tr>
<tr>
<td></td>
<td></td>
<td>- Easier prefabrication with Y elements</td>
<td></td>
</tr>
<tr>
<td></td>
<td></td>
<td>- Smaller elements, easier to transport</td>
<td></td>
</tr>
<tr>
<td><strong>Duality Steel</strong></td>
<td>1.090.000</td>
<td>- One material</td>
<td>+29%</td>
</tr>
<tr>
<td></td>
<td></td>
<td>- Slabs and atrium roof are easier to prefabricate</td>
<td></td>
</tr>
<tr>
<td></td>
<td></td>
<td>- Increased number of elements</td>
<td></td>
</tr>
<tr>
<td><strong>Duality Steel and Timber</strong></td>
<td>1.260.000</td>
<td>- Multiple materials</td>
<td>100%</td>
</tr>
<tr>
<td></td>
<td></td>
<td>- Additional prefabrication of wall elements</td>
<td></td>
</tr>
<tr>
<td></td>
<td></td>
<td>- Simpler auditorium roof structure</td>
<td></td>
</tr>
</tbody>
</table>
Cost comparison of Sprout structural options

The more flexible and compact element choice of Honeycomb option reduces the construction costs.
Cost comparison of Duality structural options

The utilization of timber and steel elements increases complexity and cost, but reduces the environmental impact.
Comparison of construction cost

Despite of the cleaner structural design, the increased floor area results in higher costs in case of the Sprout concept.
Life Cycle Financial Management
Measures to reduce LCC

M & O Costs
- PV panels
- Geo source heat pump
- Natural ventilation
- Bundling rooms with high security requirements

Impact on M&O costs:
- Avoidance of additional security measures

Impact on M&O costs:
- Energy savings: approx. 30 %
- Required savings: approx. 10 %

Risk Costs
- Usage of water-resistant materials
- Foundations that prevent the lifting of the supporting structure
- Locate MEP room in upper floors

Impact on risk costs:
- Sprout: saves ⅓ of risk costs
- Duality: potential to save ⅓ of risk costs
Life Cycle Costs

Cost strengths and weaknesses of every concepts

Different Types of Costs

- Construction Costs
- Financial Costs
- M&O Costs
- Risk Costs
- Replacement Costs

Costs [MEUR]

- Sprout - Standard
- Sprout - Honeycomb
- Duality - Steel
- Duality - Steel and Timber
Comparison of the total life cycle costs

Total Life Cycle Costs

- Sprout - Standard: 16,00 Mio. €
- Sprout - Honeycomb: 15,55 Mio. €
- Duality - Steel: 16,00 Mio. €
- Duality - Steel and Timber: 15,00 Mio. €

Costs [MEUR]
## Financial Indicators

### Economic analysis of the concepts

<table>
<thead>
<tr>
<th>Concept</th>
<th>IRR on Equity &gt; 10 %</th>
<th>NPV</th>
<th>DSCR &gt; 1,15</th>
<th>LLCR &gt; 1,25</th>
</tr>
</thead>
<tbody>
<tr>
<td>Sprout - Standard</td>
<td>10,40 %</td>
<td>1.300.000 €</td>
<td>Covered</td>
<td>Covered</td>
</tr>
<tr>
<td>Sprout - Honeycomb</td>
<td>10,37 %</td>
<td>1.250.000 €</td>
<td>Covered</td>
<td>Covered</td>
</tr>
<tr>
<td>Duality - Steel</td>
<td>10,63 %</td>
<td>1.200.000 €</td>
<td>Covered</td>
<td>Covered</td>
</tr>
<tr>
<td>Duality - Steel + Timber</td>
<td>10,46 %</td>
<td>1.300.000 €</td>
<td>Covered</td>
<td>Covered</td>
</tr>
</tbody>
</table>

<table>
<thead>
<tr>
<th>Concept</th>
<th>Rent p.a.</th>
<th>Rent p.m.</th>
</tr>
</thead>
<tbody>
<tr>
<td>Sprout - Standard</td>
<td>810.000 €</td>
<td>22,63 €/m²</td>
</tr>
<tr>
<td>Sprout - Honeycomb</td>
<td>790.000 €</td>
<td>22,07 €/m²</td>
</tr>
<tr>
<td>Duality - Steel</td>
<td>740.000 €</td>
<td>27,46 €/m²</td>
</tr>
<tr>
<td>Duality - Steel + Timber</td>
<td>770.000 €</td>
<td>28,57 €/m²</td>
</tr>
</tbody>
</table>
The matrix as a collaborative decision making

**Criteria**
Team discussion about criteria for every discipline.

**Weighting**
Team members and owners have weighted the criteria

<p>| | | |</p>
<table>
<thead>
<tr>
<th></th>
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</thead>
<tbody>
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<td>1</td>
<td>Design</td>
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<tr>
<td>2</td>
<td>Total Life Cycle Cost</td>
<td>6.3%</td>
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<tr>
<td>...</td>
<td>...</td>
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</tr>
</tbody>
</table>

**Ranking**
Every team member and every owner ranked each criteria for every concept.

<table>
<thead>
<tr>
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<th>1</th>
<th>2</th>
<th>3</th>
<th>4</th>
<th>5</th>
<th>6</th>
<th>7</th>
<th>8</th>
<th>9</th>
<th>10</th>
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</thead>
<tbody>
<tr>
<td>very worse</td>
<td>worse</td>
<td>medium</td>
<td>good</td>
<td>very good</td>
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</tbody>
</table>

**Decision**
The winner is ...
# Decision Matrix

## Result of the matrix

<table>
<thead>
<tr>
<th></th>
<th>Duality - Steel + Timber</th>
<th>Duality - Steel</th>
<th>Sprout - Standard</th>
<th>Sprout - Honeycomb</th>
</tr>
</thead>
<tbody>
<tr>
<td>General</td>
<td>0.81</td>
<td>0.87</td>
<td>0.78</td>
<td>0.83</td>
</tr>
<tr>
<td>Architecture</td>
<td>1.07</td>
<td>1.11</td>
<td>1.19</td>
<td>1.25</td>
</tr>
<tr>
<td>Engineering</td>
<td>0.73</td>
<td>0.76</td>
<td>0.77</td>
<td>0.81</td>
</tr>
<tr>
<td>Construction Management</td>
<td>0.67</td>
<td>0.68</td>
<td>0.69</td>
<td>0.76</td>
</tr>
<tr>
<td>MEP</td>
<td>0.64</td>
<td>0.66</td>
<td>0.68</td>
<td>0.70</td>
</tr>
<tr>
<td>LCFM</td>
<td>0.79</td>
<td>0.74</td>
<td>0.70</td>
<td>0.75</td>
</tr>
<tr>
<td><strong>TOTAL WEIGHTED SCORE</strong></td>
<td><strong>4.72</strong></td>
<td><strong>4.82</strong></td>
<td><strong>4.81</strong></td>
<td><strong>5.10</strong></td>
</tr>
</tbody>
</table>
Decision Matrix
Comparison of concepts
More than the three C
Applications, best practices, our favorite three words are communication, collaboration and coordination

- dedication
- work
- help
- time
- extrawork
- misunderstandings
- calls
- reduction of social life

communication

Dlubal FEM-Design

R =

advice
messages
Thank you for all the help and support!

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Gábor Tatár
Construction Manager
gabor.tatar@icloud.com

Jan Luca Grunow
Life Cycle Financial Manager
grunow.luca@web.de
Backup slides
Target Value Design Wal
Sprout - Standard

TARGET VALUE DESIGN WALL

<table>
<thead>
<tr>
<th>COST ESTIMATE</th>
<th>ESTIMATED VALUE</th>
<th>TARGET VALUE</th>
<th>VALUE DELTA</th>
</tr>
</thead>
<tbody>
<tr>
<td>Total</td>
<td>€8,200,000</td>
<td>€8,330,000</td>
<td>€130,000</td>
</tr>
</tbody>
</table>

Gross Floor Area [sqm]: 3,300
Price = 2485 €/sqm
# Target Value Design Wall

**Sprout - Honeycomb**

## Target Value Design Wall

<table>
<thead>
<tr>
<th></th>
<th>Estimated Value</th>
<th>Target Value</th>
<th>Value Delta</th>
</tr>
</thead>
<tbody>
<tr>
<td><strong>Total</strong></td>
<td>€ 8,000,000</td>
<td>€ 8,330,000</td>
<td>€ 330,000</td>
</tr>
</tbody>
</table>

**Gross Floor Area [sqm]**: 3,300

**Price**: € 2,424/sqm

### TVD - Summary

- **General Conditions**: € 615,000 (6%)
- **Site Works**: € 3,000,000 (21%)
- **Utilities**: € 1,000,000 (10%)
- **Electrical & Instrumentation**: € 2,920,000 (27%)
- **Special Labour**: € 230,000 (2%)
- **Other**: € 500,000 (5%)

### TVD - Targets by Cluster

- **A Substructure**: € 1,000,000 (14%)
- **B Shell**: € 2,000,000 (29%)
- **C Services**: € 1,500,000 (21%)
- **D Services**: € 1,800,000 (27%)
- **E Equipment and Furnishing**: € 500,000 (6%)
- **F Speciality Construction**: € 300,000 (4%)
- **G Other**: € 300,000 (4%)

### TVD - Tracking Target Over Time

**Target: Mar 10 - Apr 27**

- Estimated Value: € 8,200,000
- Actual Value: € 8,100,000

### Estimate Quantity Reliability

- **High**: 14%
- **Medium**: 8%
- **Low**: 8%

### Estimate Cost Data Reliability

- **High**: 14%
- **Medium**: 8%
- **Low**: 8%

### Estimate Overall Reliability

- **High**: 14%
- **Medium**: 8%
- **Low**: 8%
Target Value Design Wal
Duality - Steel

<table>
<thead>
<tr>
<th>TeamRiver</th>
<th>COST ESTIMATE</th>
<th>TVD - SUMMARY</th>
<th>TVD - TARGETS BY CLUSTER</th>
<th>TVD - TRACKING TARGET OVER TIME</th>
<th>ESTIMATE QUANTITY RELIABILITY</th>
<th>ESTIMATE COST DATA RELIABILITY</th>
<th>ESTIMATE OVERALL RELIABILITY</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>TOTAL</td>
<td>€ 7,500,000</td>
<td>€ 8,330,000</td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td></td>
<td>VALUE DELTA</td>
<td>€ 830,000</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
</tbody>
</table>

<table>
<thead>
<tr>
<th></th>
<th>ESTIMATED VALUE</th>
<th>TARGET VALUE</th>
<th>VALUE DELTA</th>
</tr>
</thead>
<tbody>
<tr>
<td>TOTAL</td>
<td>€ 7,500,000</td>
<td>€ 8,330,000</td>
<td>€ 830,000</td>
</tr>
</tbody>
</table>

Gross Floor Area [m²]: 2,400
Price = 3125 €/sqm
Target Value Design Wall
Duality – Steel and Timber
Structural Option Honeycomb

Analysis

Results

SHS 400x16
Life Cycle Financial Management... 

... is interdisciplinary teamwork

<table>
<thead>
<tr>
<th>Architecture</th>
<th>Floorplans</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>Increase daylight factor, “security rooms”, ...</td>
</tr>
</tbody>
</table>

<table>
<thead>
<tr>
<th>Structural Engineering</th>
<th>Risk Severity</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>flood-proof structure (e.g. foundation), ...</td>
</tr>
</tbody>
</table>

<table>
<thead>
<tr>
<th>Construction Management</th>
<th>TVD, Construction Costs</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>Construction budget, ...</td>
</tr>
</tbody>
</table>

<table>
<thead>
<tr>
<th>MEP</th>
<th>STV, Energy/Water Consumption</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>Self-supply with energy, ...</td>
</tr>
</tbody>
</table>

Life Cycle Costs
Target Value Design & Construction Costs

Construction costs are the initial investment costs and impact other cost groups.

Construction Costs and Construction Target

- Higher Construction Costs automatically lead to higher Financing Costs.
Maintenance and Operating Costs
What is that? And how can we decrease them?

Composition of M& Costs

- Supply: 36.7% (1,200,000€)
- Cost Avoidance Strategy
  - Insulation: 10.7% (350,000€)
  - Caretaker: 13.8% (450,000€)
- Cleaning: 22.9% (750,000€)
- Public Charges: 2.1% (450,000€)
- Security: 13.8% (2,100,000€)

shown using the example "Duality - Steel"

Cost Avoidance Strategy

Supply Costs
- Self-Supply
- Energy- and Water-saving Devices

Cleaning Costs
- Cleaning Robots
- Self-Cleaning Glass

Security Costs
- Technical Security Measures
- Access Control System
Risk Costs

Process of risk management and risk mitigation

Step 1
- Risk Identification -
Which dangers exist in which phases of life?

Step 2
- Risk Analysis -
What exactly happens at this specific risk?

Step 3
- Risk Evaluation -
How does this affect the building?

Step 4
- Risk Strategies -
Can we avoid the risk? If not, how can we reduce the extent of the damage?

Result of Risk Management:

<table>
<thead>
<tr>
<th>No.</th>
<th>Risk name / category</th>
<th>Description</th>
<th>Consequences</th>
<th>AEC Responsibility</th>
<th>Risk Management</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td></td>
<td></td>
<td></td>
<td>Arch</td>
<td>SE</td>
</tr>
<tr>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Planning Period</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>1.1</td>
<td>Financing Risk</td>
<td>Capital cannot be raised at the desired time or on the desired terms.</td>
<td>Delay of construction start, higher financing costs, short term loan, etc.</td>
<td></td>
<td></td>
</tr>
<tr>
<td>Construction Period</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>2.1</td>
<td>Construction Delay</td>
<td>The availability of the building is not given in time, because of (e.g.) mistakes in the construction design</td>
<td>Additional costs because of crossing the timeframe and redesign / structure the building</td>
<td>x</td>
<td>x</td>
</tr>
<tr>
<td>Operating &amp; Maintenance Period</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>3.2</td>
<td>Flooding</td>
<td>Flood, at which the water reaches the building</td>
<td>(Severe) damage to the building, which can lead to high repair costs</td>
<td>x</td>
<td></td>
</tr>
</tbody>
</table>
### Risk Cost

#### Economical calculation of risk costs

- **Risk Costs** = **Probability** * **Severity**

<table>
<thead>
<tr>
<th>Type of Risk</th>
<th>Level of Risk Cost</th>
<th>Avoidance Strategy</th>
</tr>
</thead>
<tbody>
<tr>
<td>Flooding</td>
<td>High probability * high severity</td>
<td>• Waterproof Ground Floor</td>
</tr>
<tr>
<td></td>
<td><strong>high risk costs</strong></td>
<td></td>
</tr>
<tr>
<td>Vandalism</td>
<td>High probability * mean severity</td>
<td>• Security Measures</td>
</tr>
<tr>
<td></td>
<td><strong>quite high risk costs</strong></td>
<td>• Special Facade Painting</td>
</tr>
<tr>
<td>Construction Delay</td>
<td>Mean probability * mean severity</td>
<td>• Time Buffer</td>
</tr>
<tr>
<td></td>
<td><strong>mean risk costs</strong></td>
<td>• Pre-Planning</td>
</tr>
<tr>
<td>Extremely cold winters</td>
<td>Mean probability * low severity</td>
<td>• Insulate the Building</td>
</tr>
<tr>
<td></td>
<td><strong>low risk costs</strong></td>
<td>• Self-sufficiency</td>
</tr>
</tbody>
</table>
Risk Cost
Flooding is the main risk on the site

Risk Costs = Probability * Severity

Example: Flooding

High Probability * high Severity = High Risk Costs

Strategies to reduce flooding risk costs:

1. Evasion
   Not possible on our site

2. Keeping away
   Difficult on our site

3. Transfer
   Check again

4. Adaptation

Measures:
- use of water-resistant materials (e.g. avoid wood)
- Foundations that prevent the lifting of the supporting structure
- locate MEP room in upper floors

Impact on risk costs:
- Sprout: saves ⅓ of risk costs
- Duality: could save approx. ⅓ of risk costs

Future possibilities to reduce flooding risk:
- submarine-idea
- cooperation with municipality
- underground shafts Ilm-Park
- mobile dam
Decision Matrix
Sprout - Honeycomb
Decision Matrix
Duality - Steel
Decision Matrix

Duality - Steel + Timber