River Team
2018
River Team Design Team

- **Belle**
  - Role: Structural Engineer
  - University: Stanford University
  - Location: USA

- **Vivian**
  - Role: Structural Engineer
  - University: Stanford University
  - Location: USA

- **Austin**
  - Role: Construction Manager
  - University: University of Wisconsin
  - Location: USA

- **Ethan**
  - Role: Construction Manager
  - University: Stanford University
  - Location: USA

- **Michael**
  - Role: Life Cycle Financial Manager
  - University: Bauhaus University
  - Location: Germany

- **Sylwia**
  - Role: Architect
  - University: Warsaw University of Technology
  - Location: Poland

- **Vikash**
  - Role: Mechanical Engineer
  - University: Danish Technical University
  - Location: Denmark
Owners

Renate Fruchter
USA

Luke Lombardi
USA

Ewa Kunkel
Denmark

Hussain Parsianfar
Denmark

Andrej Kurent
Slovenia
Collaboration

talking...

what?

confusion

“what are we doing?”

collaboration

action!

coordination
Increasing Frequency Of Interactions

- **Weekly meeting**
- **Subgroup meeting**
- **Mentor meeting**
Communication & Collaboration

Tools

**COMMUNICATION**

- Team conversations
  - Owners emails
  - Mentor emails

**COLLABORATION**

- Subgroup channels
  - Brainmerge
    - Engaging everyone to be creative together

  - SPAN
    - As a part of sub-group meetings
    - Collaboration on the models
      - Linking the disciplines

**Tools**

- Slack
- Gmail
- Zoom
- Autodesk BIM 360
- Nureva Span
- Ab Glue
## Pull Plan


<table>
<thead>
<tr>
<th>Date</th>
<th>I Am</th>
<th>I Get</th>
<th>I Give</th>
<th>I Need From</th>
<th>Subgroup</th>
<th>Subgroup</th>
<th>Status</th>
<th>% Complete</th>
</tr>
</thead>
<tbody>
<tr>
<td>01-03-2018</td>
<td>A: Sylvia</td>
<td>Link perimeter shape</td>
<td>Link- Facade</td>
<td>Both CM's</td>
<td>SE: Vivian</td>
<td>LCFM: Michael</td>
<td>Complete</td>
<td>100%</td>
</tr>
<tr>
<td></td>
<td>LCFM: Michael</td>
<td>STV - REFLECTION</td>
<td>STV for ripple (Concept 1 &amp; 2)</td>
<td>ME: Vikash</td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td></td>
<td>SE: Vivian</td>
<td>Construction material details - Architecture</td>
<td>Reached to 2 more structural mentors</td>
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<td></td>
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<tr>
<td>01-03-2018</td>
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<td>Construction material details - Structures</td>
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<tr>
<td></td>
<td>Both CM's</td>
<td>Construction material details - Architecture</td>
<td>Preliminary STV - Option 2 (Ripple)</td>
<td>A: Sylvia</td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td></td>
<td>All</td>
<td>Design information from A, E, MEP</td>
<td>CM suggestions &amp; price alternatives</td>
<td>All</td>
<td></td>
<td></td>
<td></td>
<td></td>
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<tr>
<td>02-03-2018</td>
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<td>Architectural floor plan finalized</td>
<td>Prefab, zones, sequence of construction</td>
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<td></td>
<td></td>
<td>Complete</td>
<td>100%</td>
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<tr>
<td>03-03-2018</td>
<td>Both SE's</td>
<td>vertical shafts, and auditorium location</td>
<td>Grid options and structural system options</td>
<td>A: Sylvia</td>
<td>A-E</td>
<td></td>
<td></td>
<td>75%</td>
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<tr>
<td></td>
<td>All</td>
<td>Sustainability and owners powerpoint</td>
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<td>04-03-2018</td>
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<td>Wind loading and optimal structural systems</td>
<td>Start on two structural options for Link</td>
<td>Both CM's</td>
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<td></td>
<td>0,25</td>
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<tr>
<td></td>
<td>Both SE's</td>
<td>Architectural floor plan finalized</td>
<td>2 structural solutions for the Ripple</td>
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<td></td>
<td></td>
<td></td>
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<tr>
<td></td>
<td>ME: Vikash</td>
<td>Architectural floor plan finalized</td>
<td>Ripple Revit model</td>
<td>Not Started</td>
<td>0</td>
<td></td>
<td></td>
<td></td>
</tr>
</tbody>
</table>
Location
Weimar, Germany
UNESCO World Heritage Site
Site Access

Maximum permitted trailer width: 2.6 m
Minimum road width: 3.5 m

possible routes
preferred routes
Site Context & Challenges

- Castle
- Main Square
- Bauhaus University
- Park an der Ilm
- Ilm River

Our site

Site limitations

Flooding from the Ilm River (350cm)
## Site Challenges

<table>
<thead>
<tr>
<th>Problem</th>
<th>Solution</th>
</tr>
</thead>
<tbody>
<tr>
<td><img src="image1" alt="Noise Icon" /></td>
<td><img src="image2" alt="Noise Solution" /></td>
</tr>
<tr>
<td><img src="image3" alt="Crowd Icon" /></td>
<td><img src="image4" alt="Crowd Solution" /></td>
</tr>
<tr>
<td><img src="image5" alt="Construction Icon" /></td>
<td><img src="image6" alt="Construction Solution" /></td>
</tr>
<tr>
<td><img src="image7" alt="Environmental Icon" /></td>
<td><img src="image8" alt="Environmental Solution" /></td>
</tr>
</tbody>
</table>
Exploring Solutions...

**Smaller Changes - Setting a Good Example**
- **Green Roof**
  - Capturing rain water
- **Permeable Paving**
  - Making it easier for water to get into the ground
- **Rainwater Harvesting**
  - Reuse of the rain water
- **Filtering Rain Water with Plants**
  - Using plants such as bulrush, soft rush, water mint

**More Radical Solutions**
- **Waterproof Groundfloor**
  - Materials that won't get damaged in case of flood
- **Temporary Water Reservoir**
  - Wall blocking the water
- **Raising the Building**

**Temporary Water Barrier during Construction**
Decision

smaller changes - setting a good example

<table>
<thead>
<tr>
<th>Green Roof</th>
<th>Rainwater Harvesting</th>
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<tbody>
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<td>reuse of the rain water</td>
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<tbody>
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<td>using plants such as bulrush, soft rush, water mint</td>
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</table>

<table>
<thead>
<tr>
<th>Waterproof Groundfloor</th>
<th>Temporary Water Barrier during Construction</th>
</tr>
</thead>
<tbody>
<tr>
<td>materials that won't get damaged in case of flood</td>
<td>wall blocking the water</td>
</tr>
</tbody>
</table>

<table>
<thead>
<tr>
<th>Temporary Water Reservoir</th>
<th>Raising the Building</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>raising the building</td>
</tr>
</tbody>
</table>

more radical solutions -
Flood Damage Mitigation

- Raising electrical system components
- Waterproof ground floor of the building

![Diagram showing levels and waterproofing](image)
**Climate Info**

**Temperature (°C)**
- Summer peak: 23 °C
- Winter peak: -4 °C

**Rainfall (mm) and days**
- Annual Rainfall: 560 mm
- Max rainfall: 68 mm

**Cloud and humidity (%)**
- Average humidity: 78%
- Peak humidity: 86%

**Snowfall (mm) and days**
- Average snowfall: 16 cm
- Maximum days: 21 in January
Wind Analysis
Sun Analysis

Summer sun path

Winter sun path
1. Minimal immediate impact and positive long term effects

2. Knowledge rippling out from the building

3. Building reacting to changing surroundings

4. Giving back the green taken away from the park

THE RIPPLE
Ripple Evolution

“Ripples aren’t square...” -Greg Luth
Ripple Site Plan
Ripple Elevations

South

West

East

North
Ripple Self-adaptable Facade
Ripple Biophilia

Green walls

Green roof

Building

Nature

People

Water
Plants
Air

CO2
O2
Ripple Semi-circular Flow
Ripple Level 1

- 4.3 m
- 18.7 m
- 15.4 m

- Lab
- Small Classroom
- Integration spaces
- Seminar Room
- Restroom
- Mechanical Room
- Storage
- Student Office
- Technical Support
Ripple Level 2
Ripple Section
Ripple Social Spaces
Student and faculty integration
Ripple Sustainability
Integration - 4 Levels

Ripple
Spatial Integration

Ilm Park, River, Castle
Bauhaus University
City of Weimar
Country/World
Ripple Integration - 4 Levels

Level 1
Park and river

Level 2
Bauhaus University

Level 3
Weimar city

Level 4
Country/World

Building

Nature
Water
Plants
Air

People
Ripple Sustainability Challenge

Level 1
Using **nature benefits** in the innovative ways

Level 2
Knowledge about **sustainable design** rippling out of the building

Level 3
not taking away from the park, but keeping **natural balance** - Inviting people on the roof

Level 4
**Tracking and sharing** building performance after the construction - taking responsibility + adjusting

[Energy use]
[CO2 level]
Structural Design Solutions

Ripple
### Soil Profile and Water Table

<table>
<thead>
<tr>
<th>Soil Type</th>
<th>Top Depth (m)</th>
<th>Bottom Depth (m)</th>
<th>Bearing Capacity (kN/m²)</th>
</tr>
</thead>
<tbody>
<tr>
<td>Mould Topsoil</td>
<td>0</td>
<td>0.508</td>
<td>-</td>
</tr>
<tr>
<td>Younger Rimstone</td>
<td>0.508</td>
<td>1.143</td>
<td>-</td>
</tr>
<tr>
<td>Keuper</td>
<td>1.143</td>
<td>1.524</td>
<td>-</td>
</tr>
<tr>
<td>Medium Shell Limestone</td>
<td>1.524</td>
<td>2.1336</td>
<td>239.4</td>
</tr>
<tr>
<td>Medium Shell Limestone</td>
<td>2.1336</td>
<td>-</td>
<td>383.04</td>
</tr>
</tbody>
</table>

Water Table 1.2192 m below grade
Ripple Foundations

Solution 1: Micropiles

- 4 piles with ø0.2m, depth 6.5m

Solution 2: Spread Footing (Cheaper)

- 0.9m below grade
- 4.88X4.88m square footing
- Column
- Grade (That means normal ground level)
- Foundation wall
- Rebar
- Footer
- More Rebar
- Basement floor pad
- Form-a-drain

Rebars (sizes TBD)

Detail from http://www.infoforbuilding.com
## Imposed Loads

<table>
<thead>
<tr>
<th>Use</th>
<th>Uniform Load (kN/m²)</th>
</tr>
</thead>
<tbody>
<tr>
<td>Student &amp; Faculty Offices</td>
<td>3.0</td>
</tr>
<tr>
<td>Small Classrooms</td>
<td>3.0</td>
</tr>
<tr>
<td>Large Classrooms</td>
<td>4.0</td>
</tr>
<tr>
<td>Corridors</td>
<td>5.0</td>
</tr>
<tr>
<td>Stairs</td>
<td>5.0</td>
</tr>
<tr>
<td>Auditorium</td>
<td>5.0</td>
</tr>
<tr>
<td>Assembly Spaces (Atrium and Roof)</td>
<td>5.0</td>
</tr>
</tbody>
</table>

*Values from Eurocodes Table 6.2, EN 1991-1-3, EN 1991-1-4, and EN 1998-1

<table>
<thead>
<tr>
<th>Use</th>
<th>Uniform Load (kN/m²)</th>
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</thead>
<tbody>
<tr>
<td>Roof</td>
<td>0.75</td>
</tr>
<tr>
<td>Green Roof</td>
<td>2.0 (saturated)</td>
</tr>
<tr>
<td>PV Roof Panels</td>
<td>0.2</td>
</tr>
<tr>
<td>Snow Load</td>
<td>0.85</td>
</tr>
<tr>
<td>Wind Load</td>
<td>0.5 (sustained) 0.1 (gust)</td>
</tr>
<tr>
<td>Earthquake Load</td>
<td>NA</td>
</tr>
</tbody>
</table>
Ripple Radical Grid Proposals
Ripple Radical Grid Proposals
Ripple Finalized Grid Dimensions

All units in meters.
Ripple Structural Solutions

Steel

Timber
Ripple Steel - 3-D Section Cuts
Ripple Steel - Coordination

305x305x97UC
HE160M
HE240M
HE450M
Compression Ring
Tension Ring
Concrete Shear Walls
Concrete Retaining Walls
Ripple Steel - Level 0 Plan

305x305x97UC
HE160M
HE240M
HE450M
Compression Ring
Tension Ring
Concrete Shear Walls
Concrete Retaining Walls
Ripple Steel - Level 1 Plan

- 305x305x97UC
- HE160M
- HE240M
- HE450M
- Compression Ring
- Tension Ring
- Concrete Shear Walls
- Concrete Retaining Walls
Ripple Steel - Roof Plan

- 305x305x97UC
- HE160M
- HE240M
- HE450M

Compression Ring
Tension Ring
Concrete Shear Walls
Concrete Retaining Walls
Ripple Steel - Vertical Load Path

- Tension
- Compression
Ripple Steel Details
Ripple Steel - Lateral Resistance

RC Shear Wall
RC Shear Wall + Moment Frame

Wind
Lateral Resistance
Ripple Timber - 3-D Section Cuts
Ripple Timber - Coordination

- Glulam 171.5x190.5
- CLT 191V Wall Panels
- Concrete Retaining Walls
  - Compression Ring
  - Tension Ring
  - Glulam 130x229
  - Glulam 171x305
  - Glulam 222x381
  - Glulam 222x533
Ripple Timber - Level 0 Plan

- Glulam 171.5x190.5
- CLT 191V Wall Panels
- Concrete Retaining Walls
- Compression Ring
- Tension Ring
  - Glulam 130x229
  - Glulam 171x305
  - Glulam 222x381
  - Glulam 222x533
Ripple Timber - Roof Plan

Glulam 171.5x190.5
CLT 191V Wall Panels
Concrete Retaining Walls
Compression Ring
Tension Ring
Glulam 130x229
Glulam 171x305
Glulam 222x381
Glulam 222x533
Ripple Curved CLT Wall

Detail from sturcturelam.com
Ripple Timber - Vertical Load Path
Ripple Timber - Lateral Resistance

- CLT Wall
- CLT Wall + Moment Frame
- Wind
- Lateral Resistance
MEP Concept

Ripple
Ripple HVAC Design Basis

- Summer design dry bulb Temp : 23°C
  - Indoor temperature : 24°C

- Winter design dry bulb : -4°C
  - Indoor temperature : 22°C

- Indoor relative humidity : 55%

- Ventilation and occupancy as per Ashrae 62.1

- Noise level : 55 db
Ripple Energy Saving Methodology

- R-50 insulation
- Heat mirror glass
- Occupancy transfer
- Occupancy schedule
- Equipment selection
- Adaptable facade
- Cantilever

- Labs
- Classroom
- Circulation
- Seminar
# Ripple Load Calculations

## Example

<table>
<thead>
<tr>
<th>Level</th>
<th>Name</th>
<th>Area (Sqmtr)</th>
<th>Occupancy</th>
<th>Unit sizing</th>
<th>Ventilation</th>
<th>Unit sizing (CFM)</th>
<th>Cooling capacity</th>
<th>Outdoor capacity</th>
</tr>
</thead>
<tbody>
<tr>
<td>Level 1</td>
<td>Auditorium</td>
<td>271</td>
<td>203</td>
<td>203</td>
<td>1687</td>
<td>1687</td>
<td>45</td>
<td>45</td>
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<tr>
<td></td>
<td>Cafe</td>
<td>67</td>
<td>13</td>
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<td>141</td>
<td>141</td>
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<td>Circulation</td>
<td>95</td>
<td>19</td>
<td>200</td>
<td>57</td>
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<td>Large Classroom</td>
<td>73</td>
<td>47</td>
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<td>400</td>
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<td>394</td>
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<td>15</td>
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<tr>
<td></td>
<td>Restroom</td>
<td>14</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td></td>
<td>Restroom</td>
<td>14</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td></td>
<td>Small Classroom</td>
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<td>33</td>
<td>274</td>
<td>274</td>
<td>11</td>
<td>11</td>
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<tr>
<td></td>
<td>Small Classroom</td>
<td>45</td>
<td>29</td>
<td>29</td>
<td>246</td>
<td>246</td>
<td>10</td>
<td>10</td>
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</table>

<table>
<thead>
<tr>
<th></th>
<th>Ripple Timber</th>
<th>Ripple Steel</th>
<th>Check sums</th>
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<tbody>
<tr>
<td>Cooling (kW)</td>
<td>396</td>
<td>409</td>
<td>148 w/ Sqmtr</td>
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<tr>
<td>Occupancy</td>
<td>955</td>
<td>955</td>
<td></td>
</tr>
<tr>
<td>Fresh air (CFM)</td>
<td>6425</td>
<td>6425</td>
<td>6.7 CFM/ person</td>
</tr>
</tbody>
</table>
### Ripple Heating and Cooling

<table>
<thead>
<tr>
<th></th>
<th>Radiant</th>
<th>Water cooled VRF</th>
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<tbody>
<tr>
<td><strong>Energy</strong></td>
<td>Highly efficient</td>
<td>Highly efficient</td>
</tr>
<tr>
<td><strong>Clear height</strong></td>
<td>More</td>
<td>Less</td>
</tr>
<tr>
<td><strong>Loading on roof</strong></td>
<td>More</td>
<td>Less</td>
</tr>
<tr>
<td><strong>Capital cost</strong></td>
<td>More</td>
<td>Less</td>
</tr>
<tr>
<td><strong>Installation time</strong></td>
<td>Less</td>
<td>More</td>
</tr>
<tr>
<td><strong>Heating</strong></td>
<td>Yes</td>
<td>Yes</td>
</tr>
</tbody>
</table>
Ripple Ventilation System

- Solid desiccant centralised ventilation system.
  - Excellent humidity control
  - Energy efficient.
Ripple Floor Sandwich 2

- Beam W18"
- VRF type FCU
- Ceiling
- 50mm high Ele. duct/ cable tray
- False ceiling
- 100mm duct height
- Clear height
- Slab to slab height
- 100mm concrete slab (62.5 mm slab+ Floor finishing)
- 30mm for under floor electrical heating
- 50mm Steel deck
Ripple Level 0 Plan

Room Legend
- Auditorium
- Cafe
- Circulation
- Large Classroom
- Restroom
- Small Classroom
- Storage

MEP shaft
Ripple Level 1 Plan

Room Legend
- Circulation
- Lab
- Lounge
- Restroom
- Seminar Room
- Small Classroom
- Storage
- Student Office
- Tech Support

MEP shaft
From L2
Ripple Roof

Mechanical room

Mechanical Room
8.0 x 6.0 x 3.0 (H) mtr

Mechanical Shaft
2.8 x 0.9 mtr
Ripple Nearly Zero-energy Building

Building yearly energy consumption

2662 Sq mtr

200 Days

25.4 kW @ 0.9 w/ Sqft

33.9 kW @ 1.2 w/ Sqft

165 Days

88 kW

154,393 kW per year
Ripple Nearly Zero-energy Building

Roof design as a product of A-E-MEP collaboration

590 Sq Mtr PV on south roof
Ripple Nearly Zero-energy Building

PV Power generation

20 w/Sqft power generation

Power consumed - 154,393 kWH
Power produced - 159,875 kWH
Construction Analysis

Ripple
Decomposed Granite Temporary Road
Ripple Site Layout

- Entrance/Exit
- Upgraded Erosion Control Fencing
- Material Storage and Staging
- Frequent Crane Traffic - Safety Hazard Zone
- Parking
Construction Cost Estimation

Target Value
€7.05 Million

- 32% Substructure
- 28% Shell
- 13% Interiors
- 7% Services
- 6% Equipment and Furnishings
- 5% Specialty Construction
- 4% Building Sitework
- 5% General Conditions

Inputs
- RS Means SF estimates
- Previous Projects
- Owner’s Input
- Team’s Input
Ripple Construction Costs

Ripple - Timber
€ 6.8 Million

Ripple - Steel
€ 6.9 Million

- A Substructure: 34%
- B Shell: 9%
- C Interiors: 13%
- D Services: 8%
- E Equipment and Furnishing: 1%
- F Specialty Construction: 2%
- G Building Sitework: 31%
- H General Conditions: 2%
Ripple Steel Schedule

Project Duration: 155 Days

<table>
<thead>
<tr>
<th>Milestone</th>
<th>Date</th>
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</thead>
<tbody>
<tr>
<td>Construction Start</td>
<td>9/30/2024</td>
</tr>
<tr>
<td>Structure Enclosed</td>
<td>2/13/2025</td>
</tr>
<tr>
<td>Services Complete</td>
<td>4/17/2025</td>
</tr>
<tr>
<td>Construction End</td>
<td>5/2/2025</td>
</tr>
</tbody>
</table>
# Ripple Timber Schedule

<table>
<thead>
<tr>
<th>Milestone</th>
<th>Date</th>
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<td>2/13/2025</td>
</tr>
<tr>
<td>Services Complete</td>
<td>4/24/2025</td>
</tr>
<tr>
<td>Construction End</td>
<td>5/19/2025</td>
</tr>
</tbody>
</table>

## Project Duration: 166 Days

<table>
<thead>
<tr>
<th>Milestone</th>
<th>Date</th>
</tr>
</thead>
<tbody>
<tr>
<td>Preliminaries</td>
<td></td>
</tr>
<tr>
<td>Substructure</td>
<td></td>
</tr>
<tr>
<td>Prefab</td>
<td></td>
</tr>
<tr>
<td>Superstructure</td>
<td></td>
</tr>
<tr>
<td>Interior Finishing</td>
<td></td>
</tr>
<tr>
<td>Services Floor 3</td>
<td></td>
</tr>
<tr>
<td>Services Floor 2</td>
<td></td>
</tr>
<tr>
<td>Services Floor 1</td>
<td></td>
</tr>
<tr>
<td>Services Commissioning</td>
<td></td>
</tr>
<tr>
<td>Furnishings</td>
<td></td>
</tr>
<tr>
<td>Testing and Commissioning</td>
<td></td>
</tr>
</tbody>
</table>

- 9/30
- 5/19
- 5/25
THE LINK

Link -- Collegamento -- Verknüpfung -- Łącznik -- 链接 -- कड़ी
1. Linking present and the past
2. Modern factory - Bauhaus idea “School of building”
3. Linking the building with the community - informative interactive facade
Team **brainstorming**

**Massing model**
made by SEs

**Design development**
Link Site Plan
Link Maker Space
Link to the past and Bauhaus workshops

Dedicated seminar room

Cafe and product exhibition space
Link  Level 1

18 m  17 m

14.7 m
20 m

Student Office
Faculty Office
Lab
Integration steps
Maker space
Restroom
Shaft
Storage
Link  Level 1
Link - Steps as a Social Space
Integration of students and linking building with the nature
Link - Steps as a Social Space
Integration of students and linking building with the nature

Maker space
Link
Sustainability

Link
Integration Over Time

Ilm Park, River, Castle
Bauhaus University
City of Weimar
Country/World
Structural Design Solutions

Link
Prefabrication

Structurally Efficient

Aesthetics
Link Structural Solutions

Steel

Masonry Walls and Steel
Link Steel - 3-D Section Cuts
Link Steel - Level 0 Plan
Link Steel - Level 2 Plan
Link Steel - Roof Plan

- HE450M
- HE500AA
- HE450AA
- HE400B
- HE260A
- 305x305x118UC
- Concrete Shear Wall
- Concrete Foundation Wall
Link Steel - Vertical Load Path
Link Steel - Vertical Load Path

Tension

Compression
Link: Masonry - 3-D Section Cuts
Link Masonry - Level 0 Plan

- HE450M
- HE500AA
- HE450AA
- HE400B
- HE260A

305x305x118UC

Concrete Foundation Wall

0.3m Masonry Wall
Link Masonry - Level 1 Plan

HE450M
HE500AA
HE450AA
HE400B
HE260A
305x305x118UC
Concrete Foundation Wall
8" Load-bearing Masonry Wall
Link Masonry - Level 2 Plan

HE450M
HE500AA
HE450AA
HE400B
HE260A

305x305x118UC
Concrete Foundation Wall
0.3m Masonry Wall
Link Masonry - Roof Plan

- HE450M
- HE500AA
- HE450AA
- HE400B
- HE260A

305x305x118UC
Concrete Foundation Wall
0.3m Masonry Wall
Link: Masonry - Vertical Load Path

- Tension
- Compression
Link Masonry - Lateral Resistance

RC-Brick Composite
RC-Brick Composite + Moment Frame

Wind
Lateral Resistance
Truss and Suspended Stair

Detail of hanging stair in Ancestry.com headquarters building. 
https://raptstudio.com/work/ancestry/
Auditorium Span Evolution
MEP Concept

Link
## Link Load Calculations

### Example

<table>
<thead>
<tr>
<th>Level</th>
<th>Name</th>
<th>Area (Sqmtr)</th>
<th>Occupancy</th>
<th>Unit sizing</th>
<th>Ventilation</th>
<th>Unit sizing (CFM)</th>
<th>Cooling capacity</th>
<th>Outdoor capacity</th>
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<tr>
<td>Level 1</td>
<td>Auditorium</td>
<td>271</td>
<td>203</td>
<td>203</td>
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<td>Cafe</td>
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<tr>
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<tr>
<td></td>
<td>Restroom</td>
<td>14</td>
<td></td>
<td></td>
<td></td>
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<td></td>
<td>Restroom</td>
<td>14</td>
<td></td>
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<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td></td>
<td>Small Classroom</td>
<td>50</td>
<td>33</td>
<td>33</td>
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<td>Small Classroom</td>
<td>45</td>
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<td>246</td>
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<table>
<thead>
<tr>
<th></th>
<th>Link Steel</th>
<th>Link Masonry</th>
<th>Check sums</th>
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<tbody>
<tr>
<td>Cooling (kW)</td>
<td>329</td>
<td>343</td>
<td>139 W/ Sqmtr</td>
</tr>
<tr>
<td>Occupancy</td>
<td>874</td>
<td>874</td>
<td></td>
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<tr>
<td>Fresh air (CFM)</td>
<td>6313</td>
<td>6313</td>
<td>7.2 CFM/ person</td>
</tr>
</tbody>
</table>
Link Level 0 Plan

Room Legend

- Auditorium
- Cafe
- Corridor
- Entrance Hall/Factory exhibit
- Restroom
- Seminar Room
- Small Classroom
- Storage Room

MEP shaft
Link Level 2 Plan

Room Legend

- Adm. Assistant
- Corridor
- Department Chair Office
- Faculty Office
- Large Classroom
- Open Faculty Lounge
- Restroom
- Seminar Room
- Seminar Room/Maker Sp
- Senior Administration
- Storage Room

MEP shaft
Link Roof

Mechanical Room
8.0 x 6.0 x 3.0 (H) mtr

Mechanical Shaft
4.0 x 1.0 mtr
Sustainable Target Value

Ripple - Steel

Ripple - Timber

Link - Steel

Link - Masonry
Construction Analysis

Link
Link Site Plan
Link Site Layout

- Entrance/Exit
- Upgraded Erosion Control Fencing
- Material Storage and Staging
- Frequent Crane Traffic - Safety Hazard Zone

Parking
**Link** Site Layout

- Entrance/Exit
- Upgraded Erosion Control Fencing
- Material Storage and Staging
- Frequent Crane Traffic - Safety Hazard Zone
- Construction site reduction

Parking

**Site Layout:**

- **BUILDING FOOTPRINT**
- **ILM RIVER**
- **Entrance/Exit**
- **Upgraded Erosion Control Fencing**
- **Material Storage and Staging**
- **Frequent Crane Traffic - Safety Hazard Zone**
- **Construction site reduction**

[Diagram of site layout with labeled areas and directions]
Link Zoning

1st phase of construction
- Laydown of material

2nd phase of construction

Shaft to move material inside

Level 2

Level 1

Level 0
Link Construction Costs

Link - Steel
€ 5.8 Million

Link - Masonry
€ 6.1 Million

- A Substructure
- B Shell
- C Interiors
- D Services
- E Equipment and Furnishing
- F Specialty Construction
- G Building Sitework
- H General Conditions
## Link Steel Schedule

<table>
<thead>
<tr>
<th>Milestone</th>
<th>Date</th>
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<tbody>
<tr>
<td>Construction Start</td>
<td>9/30/2024</td>
</tr>
<tr>
<td>Structure Enclosed</td>
<td>1/2/2025</td>
</tr>
<tr>
<td>Services Complete</td>
<td>3/4/2025</td>
</tr>
<tr>
<td>Construction End</td>
<td>4/9/2025</td>
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Project Duration: 137 Days
## Link Masonry Schedule

<table>
<thead>
<tr>
<th>Milestone</th>
<th>Date</th>
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<tbody>
<tr>
<td>Construction Start</td>
<td>9/30/2024</td>
</tr>
<tr>
<td>Structure Enclosed</td>
<td>1/8/2025</td>
</tr>
<tr>
<td>Services Complete</td>
<td>3/13/2025</td>
</tr>
<tr>
<td>Construction End</td>
<td>4/21/2025</td>
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</tbody>
</table>

**Project Duration:** 146 Days
Map of Local Suppliers

LEGEND:
- CLT Supplier
- Steel Supplier
- Equipment Rent
- Gypsum Partition Supplier
- Concrete Supplier
- Masonry Supplier
Waste Management Plan

II. Diversion Plan and Estimates

<table>
<thead>
<tr>
<th>Material</th>
<th>Recycle/Reuse/Salvage</th>
<th>Destination</th>
<th>Estimated Tonnage</th>
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</thead>
<tbody>
<tr>
<td>Dirt/Sand/Soil</td>
<td>Recycled</td>
<td>Simi Valley Landfill and Recycling Center</td>
<td></td>
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<tr>
<td></td>
<td>Reused on Site</td>
<td>Other:</td>
<td></td>
</tr>
<tr>
<td></td>
<td>Salvaged for Future Use</td>
<td>Other:</td>
<td></td>
</tr>
<tr>
<td>Concrete</td>
<td>Recycled</td>
<td>Simi Valley Landfill and Recycling Center</td>
<td></td>
</tr>
<tr>
<td></td>
<td>Reused on Site</td>
<td>Other:</td>
<td></td>
</tr>
<tr>
<td></td>
<td>Salvaged for Future Use</td>
<td>Other:</td>
<td></td>
</tr>
<tr>
<td>Drywall</td>
<td>Recycled</td>
<td>Simi Valley Landfill and Recycling Center</td>
<td></td>
</tr>
<tr>
<td></td>
<td>Reused on Site</td>
<td>Other:</td>
<td></td>
</tr>
<tr>
<td></td>
<td>Salvaged for Future Use</td>
<td>Other:</td>
<td></td>
</tr>
</tbody>
</table>
Crane Options

Tower Crane

Mobile Crane

Benefits

RENT

Erection Time
Ripple Crane Choice

**TOWER CRANE**

**Benefits**

- **RENT**
MOBILE CRANE
Site Safety

Evacuation Meeting Area

Wearable Safety

- Myo Gesture Control
- Smart Glasses
- Spot-r Clips

SITE SAFETY
- All visitors and drivers must report to site office
- Children must not play on this site
- Foot protection must be worn
- Safety helmets must be worn
- High visibility jackets must be worn
- No unauthorised persons allowed on this site
- Danger Construction site
- Parents should warn children of potential hazards
Life-Cycle-Financial-Management
Interdisciplinary Collaboration

MEP – Vikash

Sustainable Target Value
Carbon (kgCO2e)
Water (kWh2o)
Energy (MJ)

LC-Costs reduce by PV?

Avoid long dark narrow corridors! 😊

ARCHITECT – Sylwia

LIFE – CYCLE – COST – ANALYSIS

LCFM – Michael

Decrease construction price, and waterproof 1. floor! 😊

Risk severity and consequences

CM – Eithan & Austin

SE – Belle & Vivian
M&O Cost Reduction Strategies

- 750,000 € using Photovoltaic
- 220,000 € using Purification robots
- 600,000 € using Cloud-based Server

Life-Cycle M & O Costs

<table>
<thead>
<tr>
<th>Category</th>
<th>Cost</th>
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<tbody>
<tr>
<td>Basis</td>
<td>5,320,000 €</td>
</tr>
<tr>
<td>Photovoltaik</td>
<td>4,570,000 €</td>
</tr>
<tr>
<td>Purification Robots</td>
<td>4,350,000 €</td>
</tr>
<tr>
<td>Cloud-based Server</td>
<td>3,750,000 €</td>
</tr>
</tbody>
</table>

The costs belong to: RIPPLE - Steel
TVD Cost Comparisons

€ 6.8 Mil.  € 6.9 Mil.  € 5.8 Mil.  € 6.1 Mil.  € 7.1 Mil.

Cost (Millions of Euros)

- Ripple Timber
- Ripple Steel
- Link Steel
- Link Masonry
- TVD Target

Legend:
- General Conditions
- Building Sitework
- Specialty Construction
- Equipment and Furnishing
- Services
- Interiors
- Shell
- Substructure
Risk Management Methodology

**RISK IDENTIFICATION:**
What risks may occur?

**RISK EVALUATION:**
Probability & Severity

**RISK COSTS**

**RISK STRATEGIES:**
Avoid/ Mitigate/ Accept/ Transfer

### Evaluation

- **Probability**
  - Very Low (0.01)
  - Low (0.15)
  - Medium (0.3 - 0.65)
  - High (0.7 - 1)
  - Very High (>1.6)

- **Severity**
  - Very Low (0.01)
  - Low (0.15)
  - Medium (0.3 - 0.65)
  - High (0.7 - 1)
  - Very High (>1.6)

### Strategies
- **Avoid**
  - Eliminate cause of risk
- **Mitigate**
  - Reduce probability or impact of risk
- **Accept**
  - Contingency plans for risks
- **Transfer**
  - Have third party take on responsibility of risk (e.g., insurance)

---

**Category**
- Environment
  - Ground risks
  - Fire
  - Vandalism risk
- Construction
  - Labor accident
  - Labor skills level
  - Working hour restrictions
  - Material procurement
  - Material storage
- Project
  - Planning risks
- Financial
  - Demand risk
  - Tenant insolvency
- Location
  - Flooding risk
  - Crashing trees
  - Storm damage
  - Snow load risks
## Critical Risk Items

**Formula:**

\[
\text{Risk} = \text{Probability} \times \text{Severity}
\]

<table>
<thead>
<tr>
<th>RISK CATEGORIES</th>
<th>PROBABILITY</th>
<th>SEVERITY</th>
<th>CALCULATION</th>
<th>STRATEGY</th>
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<tbody>
<tr>
<td>Flood Risk</td>
<td>0.9</td>
<td>0.8</td>
<td>0.72</td>
<td><strong>Mitigate:</strong> special constructions, waterproof first floor</td>
</tr>
<tr>
<td>Fire Risk</td>
<td>0.2</td>
<td>0.9</td>
<td>0.18</td>
<td><strong>Avoid:</strong> extinguishing system</td>
</tr>
<tr>
<td>Vandalism Risk</td>
<td>0.7</td>
<td>0.2</td>
<td>0.14</td>
<td><strong>Avoid:</strong> Security cameras, Budget buffer, Access control system</td>
</tr>
<tr>
<td>Financial Risk</td>
<td>0.2</td>
<td>0.3</td>
<td>0.06</td>
<td><strong>Mitigate:</strong> Budget buffer</td>
</tr>
<tr>
<td>Construction Delay</td>
<td>0.2</td>
<td>0.3</td>
<td>0.06</td>
<td><strong>Mitigate:</strong> Time Buffer, Pre-Planning</td>
</tr>
</tbody>
</table>
LIFE – CYCLE – COST – ANALYSIS

RIPPLE – Steel
RIPPLE – Timber

LINK – Steel
LINK – Masonry
Life-cycle-costs by Category

- Replacement Costs: €1.19 Mio., €1.19 Mio., €1.05 Mio., €1.05 Mio.
- Risk Surcharges: €0.77 Mio., €0.78 Mio., €0.65 Mio., €0.67 Mio.
- Financial Costs: €2.49 Mio., €2.45 Mio., €2.15 Mio., €2.0 Mio.

Legend:
- RIPPLE - Steel
- RIPPLE - Timber
- Link - Masonry
- Link - Steel
Life-cycle-costs / Rent Comparison

Life-Cycle-Costs

<table>
<thead>
<tr>
<th>Years</th>
<th>LCC over 25 years</th>
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<tbody>
<tr>
<td>15,1 Mio. €</td>
<td><img src="image1.jpg" alt="Graph showing Life-Cycle-Costs" /></td>
</tr>
<tr>
<td>14,8 Mio. €</td>
<td><img src="image2.jpg" alt="Graph showing Life-Cycle-Costs" /></td>
</tr>
<tr>
<td>13,0 Mio. €</td>
<td><img src="image3.jpg" alt="Graph showing Life-Cycle-Costs" /></td>
</tr>
<tr>
<td>12,7 Mio. €</td>
<td><img src="image4.jpg" alt="Graph showing Life-Cycle-Costs" /></td>
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Annual Rent

<table>
<thead>
<tr>
<th>Years</th>
<th>Annual Rent</th>
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<tbody>
<tr>
<td>722,000 €</td>
<td><img src="image5.jpg" alt="Graph showing Annual Rent" /></td>
</tr>
<tr>
<td>706,000 €</td>
<td><img src="image6.jpg" alt="Graph showing Annual Rent" /></td>
</tr>
<tr>
<td>650,000 €</td>
<td><img src="image7.jpg" alt="Graph showing Annual Rent" /></td>
</tr>
<tr>
<td>626,000 €</td>
<td><img src="image8.jpg" alt="Graph showing Annual Rent" /></td>
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</table>
LCC-analysis Summary

<table>
<thead>
<tr>
<th></th>
<th>RIPPLE – Steel</th>
<th>RIPPLE – Timber</th>
<th>LINK – Masonry</th>
<th>LINK – Steel</th>
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<tbody>
<tr>
<td><strong>Construction Costs</strong></td>
<td>6.900.000 €</td>
<td>6.800.000 €</td>
<td>6.100.000 €</td>
<td>5.800.000 €</td>
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<tr>
<td><strong>M &amp; O Costs</strong></td>
<td>3.730.000 €</td>
<td>3.720.000 €</td>
<td>3.200.000 €</td>
<td>3.200.000 €</td>
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<tr>
<td><strong>Replacement Cost</strong></td>
<td>1.190.000 €</td>
<td>1.190.000 €</td>
<td>1.050.000 €</td>
<td>1.050.000 €</td>
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<tr>
<td><strong>Risk Surcharges</strong></td>
<td>770.000 €</td>
<td>780.000 €</td>
<td>650.000 €</td>
<td>670.000 €</td>
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<tr>
<td><strong>Financial Costs</strong></td>
<td>2.500.000 €</td>
<td>2.450.000 €</td>
<td>2.150.000 €</td>
<td>2.000.000 €</td>
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<tr>
<td><strong>Total Life Cycle Costs</strong></td>
<td>15.100.000 €</td>
<td>14.800.000 €</td>
<td>13.000.000 €</td>
<td>12.700.000 €</td>
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<tr>
<td><strong>Life Cycle Costs p.a.</strong></td>
<td>604.000 €</td>
<td>592.000 €</td>
<td>520.000 €</td>
<td>508.000 €</td>
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<td><strong>Rent p.a.</strong></td>
<td>722.000 €</td>
<td>706.000 €</td>
<td>650.000 €</td>
<td>626.000 €</td>
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<tr>
<td><strong>Rent p.a. / m²</strong></td>
<td>268 €</td>
<td>262 €</td>
<td>265 €</td>
<td>255 €</td>
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# Economic Analysis Summary

<table>
<thead>
<tr>
<th>Economic Values</th>
<th>THE RIPPLE – Steel</th>
<th>THE RIPPLE – CLT</th>
<th>LINK – Masonry</th>
<th>LINK – Steel</th>
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</thead>
<tbody>
<tr>
<td>Discount rate (WACC)</td>
<td>5.08 %</td>
<td>5.08 %</td>
<td>5.08 %</td>
<td>5.08 %</td>
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<tr>
<td>Break – Even</td>
<td>2039</td>
<td>2040</td>
<td>2040</td>
<td>2040</td>
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<tr>
<td>IRR on Equity</td>
<td>14.73 %</td>
<td>14.24 %</td>
<td>14.81 %</td>
<td>14.58 %</td>
</tr>
<tr>
<td>Minimum DSCR</td>
<td>1.41</td>
<td>1.54</td>
<td>1.25</td>
<td>1.53</td>
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<tr>
<td>Minimum LLCR</td>
<td>2.09</td>
<td>2.05</td>
<td>2.08</td>
<td>2.07</td>
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<tr>
<td>Net Present Value</td>
<td>2,184,000 €</td>
<td>2,020,000 €</td>
<td>1,886,730 €</td>
<td>1,753,000 €</td>
</tr>
</tbody>
</table>

## Cash-Flow Comparison RIPPLE

- Cash-Flow RIPPLE - Steel
- Cash-Flow RIPPLE - Timber
- Cash-Flow LINK - Masonry
- Cash-Flow: LINK - Steel
Decision Matrix Methodology

Factors

Team and Owner brainstorming on decision factors

Scoring

Individual team and individual owner scoring of each concept.

Weighting

Individual Team and Owner Weighting!
<table>
<thead>
<tr>
<th>Factors</th>
<th>RIPPLE – Steel</th>
<th>RIPPLE – Timber</th>
<th>LINK – Steel</th>
<th>LINK – Masonry</th>
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</thead>
<tbody>
<tr>
<td><strong>1. Costs</strong></td>
<td></td>
<td></td>
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<tr>
<td>1.1 Construction Costs</td>
<td>1,7</td>
<td>1,8</td>
<td>2,8</td>
<td>2,3</td>
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<td>1.2 Life-Cycle-Costs</td>
<td>2,8</td>
<td>2,8</td>
<td>3,2</td>
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<tr>
<td>1.3 Annual Rent</td>
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<td>1,3</td>
<td>1,3</td>
<td>1,3</td>
</tr>
<tr>
<td><strong>2. Design</strong></td>
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Spider-diagram of Decision Matrix Result
... and the Winner is:

RIPPLE - Timber
Future Work - Accessible Design