Shading Effect of Alley Trees and Their Impact on Indoor Comfort

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The Issue

■ UHI  energy efficiency

■ Urban heat island → summer heat stress → health problems
■ Trying to create a tolerable indoor comfort → mechanical cooling → drastic increase of electricity-use during the summer period
■ EU aims to mitigate energy consumption in building sector (EPBD recast: nZEB, EED)
■ Green Infrastructure development goals (EU Biodiversity Strategy 2020)
Analysis

Aims:

• investigate the importance of shading effect of alley trees on indoor thermal comfort
• analyse species-dependence of the effect
• form a base for targeted model development/adaptation (e.g. i-Tree)
Field measurements

Study area:
Szeged (Hungary)

Tree species:
Sophora japonica
Tilia cordata
Celtis occidentalis
Transmissivity measurements:

• the indicator of shading effect (ratio of irradiance (shortwave radiation) in shaded and reference point)

• Measurements were made for vertical plane

• Kipp&Zonen CNR 1,2 pyranometers

• 3*2 measurement days
Results 1.

Common hackberry 1

Japanese pagoda 1

Common hackberry 2

Japanese pagoda 2
Results II.

<table>
<thead>
<tr>
<th></th>
<th>$\tau$ (%)</th>
<th>$\sigma$ (%)</th>
</tr>
</thead>
<tbody>
<tr>
<td>Celtis occ.</td>
<td>11,3</td>
<td>7,5</td>
</tr>
<tr>
<td>Sophora j.</td>
<td>16,6</td>
<td>7,6</td>
</tr>
<tr>
<td>Tilia cord.</td>
<td>12,0</td>
<td>7,6</td>
</tr>
</tbody>
</table>

- high variability of transmissivity values
- influence of tree condition
- considerable differences between species in radiance transmissivity
  ➔ effects on indoor thermal comfort
Modelling

- Modelling was carried out with Autodesk ECOTECT software.
- Aim is to give more general approach of the shading effect of alley trees.
- Measurements were carried out on an ideal model.

- **The model** consists of a cubic room: 12 x 6 x 4 m.
- **Wall:** thin brick structure covered with plaster.
- **Windows:** double glazed, timber framed.
- **Tree:** spherical polygons, material transparency is taken from the pyranometer measurements.
- **Modelling day:** typical summer day (16\textsuperscript{th} July).
Shaded by Small-leaved linden
Shaded by Japanese pagoda
Shaded by Common hackberry

Modelling

Total Radiation
Value Range: 400 - 1200 Wh
© ECOTECT
## Results

### Cumulative value of solar gain on vertical surface [kWh]

<table>
<thead>
<tr>
<th></th>
<th>Case without tree</th>
<th>Shadowed by Common hackberry</th>
<th>Shadowed by Japanese pagoda</th>
<th>Shadowed by Small-leaved lime</th>
</tr>
</thead>
<tbody>
<tr>
<td><strong>Average</strong></td>
<td>1,98</td>
<td>0,81</td>
<td>1,60</td>
<td>1,49</td>
</tr>
<tr>
<td><strong>Minimum</strong></td>
<td>1,72</td>
<td>0,46</td>
<td>1,18</td>
<td>1,05</td>
</tr>
<tr>
<td><strong>Maximum</strong></td>
<td>2,00</td>
<td>1,28</td>
<td>1,92</td>
<td>1,90</td>
</tr>
<tr>
<td><strong>Rate of reduction in percent</strong></td>
<td>0%</td>
<td>60%</td>
<td>19,30%</td>
<td>24,80%</td>
</tr>
</tbody>
</table>
Modelling

Tilia cord.

Total Radiation
Value Range: 400 - 1200 Wh
© ECOTECT US
## Results

<table>
<thead>
<tr>
<th>Cumulative value of solar gain on horizontal surface [kWh]</th>
</tr>
</thead>
<tbody>
<tr>
<td><strong>Case without tree</strong></td>
</tr>
<tr>
<td><strong>Average</strong></td>
</tr>
<tr>
<td>Minimum</td>
</tr>
<tr>
<td>Maximum</td>
</tr>
<tr>
<td>Rate of reduction in percent</td>
</tr>
</tbody>
</table>
Results

HOURLY TEMPERATURES - SJOBA

NOTE: Values shown are environment temperatures, not air temperatures.
**Results**

**Investigating indoor temperatures**

- **Three wall types:**

<table>
<thead>
<tr>
<th></th>
<th>heavy-weight</th>
<th>light-weight</th>
</tr>
</thead>
<tbody>
<tr>
<td>insulated</td>
<td>Concrete wall with 18 cm thermal insulation.</td>
<td>Wooden wall with 16 cm thermal insulation.</td>
</tr>
<tr>
<td></td>
<td>U-value: [0.17 W/m²K]</td>
<td>U-value: [0.18 W/m²K]</td>
</tr>
<tr>
<td>not insulated</td>
<td>Brick wall, plastered,</td>
<td></td>
</tr>
<tr>
<td></td>
<td>U-value: [1.01 W/m²K]</td>
<td></td>
</tr>
</tbody>
</table>

- **Window opening scenarios**
Results

Indoor air temperatures in different cases (structures and shading scenarios) on a typical summer day

- Outside temperature
- Concrete wall, without tree
- Concrete wall, shaded by Japanese pagoda
- Wood wall, without tree
- Wood wall, shaded by Japanese pagoda
- Brick wall, without tree
- Brick wall, shaded by Japanese pagoda

Air temperature [°C]

Hours of the day
Results

Potential of natural ventilation

Air temperature [°C] vs. Hours of the day

- Outside temperature [°C]
- Closed window, shaded by c. hackberry
- Open window, shaded by c. hackberry
- Closed window without tree
- Open window without tree
Summarising results

• Trees have an important role in mitigating total radiation on building facades and indoor surfaces.
• The effectivity of shading depends mainly on vertical transmissivity, which is a species-dependent characteristic of trees.
• A tree in front of the building
  • Diminishes the total irradiance on vertical surface up to 60%.
  • mitigates indoor temperature by \( \Delta T_{air,\text{max}} = 0.6-0.8^\circ\text{C} \).
  • Improves the potential of natural ventilation.

The operating hours of air conditioning device are mitigated / or even the installation can be avoided.
Discussion and further plans

• further measurements and model-based assessments from different study areas (species, climatic circumstances and modelling contexts)
• go on with further transmissivity measurements of different species
• Verifying the model-based results with indoor measurements.

• planting guide: model-based impact assessments of trees of different species, direction and distance to building
• urban-scale (spatial) assessments
Thank you for your attention!