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Influence of building use on comfort and energy performance in offices

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SUMMARY
This paper investigates the influence of different building use by companies and individual occupants on thermal and visual comfort, energy consumption and CO₂ emissions in mixed mode offices. Adaptive thermal comfort evaluation according to EN 15251 has been used during natural ventilation and cooling.

KEYWORDS
Variable building use, mixed mode, adaptive thermal comfort, visual comfort, CO₂ emissions

INTRODUCTION
According to the Fourth Assessment Report of the Intergovernmental Panel on Climate Change (IPCC 2007) the buildings sector has the greatest potential for climate change mitigation. For Europe, EN 15251 (2007) recommends simulation input parameters for design and assessment of energy performance of buildings concerning the indoor environment. It also refers to the significance of the way occupants use buildings. This paper shows an example regarding the influence of variable building use by occupants on comfort and energy performance in mixed mode offices, using the building simulation software EnergyPlus. The modelled room is a cellular office with typical properties for the climate of Athens, Greece.

METHODS
Approaching real building use by using the ideal and worst case scenarios
Regarding comfort, energy consumption and CO₂ emissions of buildings there are two main categories of influence. One is the building itself, its properties and design which is mainly influenced by architects, engineers and their clients. The other is the use of the building by its owners, tenants or individual occupants. However, the use of the building is difficult to predict. It depends on tasks, level of prestige/costs, consciousness for green issues and individual preferences. Therefore it is likely to vary from one company to another and among different tenants in one building. For this reason an ideal and worst case scenario has been used, on a company as well as on an individual level. The former refers to parameters, which are usually predefined on company level for all individual occupants. And the latter refers to parameters which can be used differently by individual occupants within the company. The ideal scenario represents from comfort and energy point of view the optimum (commercially available or comfort influencing) use, the worst case scenario the least optimized use. These extreme case scenarios are not aimed to represent real building use in practice. But they can help to demonstrate the range of influence different building use has on comfort and energy performance in offices. The chosen scenarios for the case study are described in table 1.
Adaptive thermal comfort evaluation

Regarding thermal comfort evaluation, EN 15251 differentiates between buildings with and without mechanical cooling. However in mixed mode buildings in Athens users are exposed to room temperatures influenced by the outside climate for most part of the year, with a typical cooling period of only a few months. And as indicated by Brager et al. (2007), an adaptive thermal comfort approach might be applicable in mixed mode buildings during cooling period as well. In this case study the adaptive thermal comfort criteria according to EN 15251 is therefore applied also during cooling period. Although further validation would be needed, this indicates the optimization potential of adaptive cooling set points in mixed mode buildings.

<table>
<thead>
<tr>
<th>Fixed parameters:</th>
<th>solid wall facade (U=0,5W/m²K), solid floor with screed, light interior walls, suspended acoustic ceiling, standard glazing (U=2,7W/m²K), window area= 70%, external venetian blind, overhang 1m, office occupied by 3 persons, designated thermal comfort class according to EN 15251 = II</th>
</tr>
</thead>
<tbody>
<tr>
<td>Influencing parameters on company level</td>
<td>- Desktop computers</td>
</tr>
<tr>
<td></td>
<td>- standard lighting system</td>
</tr>
<tr>
<td>Influencing parameters by individual office occupants</td>
<td>- blinds closed all day (passive user)</td>
</tr>
<tr>
<td></td>
<td>- light on all day (passive user)</td>
</tr>
<tr>
<td></td>
<td>- devices not disconnected at night</td>
</tr>
<tr>
<td></td>
<td>- windows not opened outside office hours</td>
</tr>
</tbody>
</table>

Table 1: parameters used in the case study influencing comfort, energy consumption + CO₂ emissions

Figure 1: a) full view, no shading b) limited view, slat angle 45° c) no view, slat angle 10°
**Visual comfort evaluation**

Visual comfort in this study refers mainly to daylight autonomy and view. Regarding view, a simple quantitative visual methodology has been used comparing the percentage of working time with full, medium or no view for the specific configuration of window area and slat angle of the shading. Example visualizations are shown in figure 1.

**Energy consumption and CO\textsubscript{2} emissions**

End energy consumption is calculated for heating, cooling, lighting, and office equipment, since these parameters all affect thermal comfort and running costs of the building. Consumption for lighting is based on two different lighting designs according to EN 12464-1 (2002), for office equipment it is based on data from the European Community Energy Star Programme. Energy consumption for heating assumes a coefficient of performance (COP) of 0.85; the COP for cooling is assumed to be 3.0. CO\textsubscript{2} emissions are calculated based on primary energy factors for Greece.

**RESULTS**

**Case study: different building use on company and individual level**

<table>
<thead>
<tr>
<th></th>
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</tr>
</thead>
<tbody>
<tr>
<td>max. cooling set point to reach comfort class II</td>
<td>25°C</td>
<td>25°C</td>
<td>28°C</td>
<td>29°C</td>
</tr>
<tr>
<td>Peak cooling load [W]</td>
<td>1945</td>
<td>1827</td>
<td>882</td>
<td>685</td>
</tr>
<tr>
<td>End energy total [kWh/m\textsuperscript{2}a]</td>
<td>264</td>
<td>224</td>
<td>99</td>
<td>78</td>
</tr>
<tr>
<td>CO\textsubscript{2} emissions total [g/MJ/a]</td>
<td>4,240,000</td>
<td>3,591,000</td>
<td>1,580,000</td>
<td>1,236,000</td>
</tr>
<tr>
<td>Full view [%]</td>
<td>0</td>
<td>29</td>
<td>0</td>
<td>29</td>
</tr>
<tr>
<td>Daylight autonomy [%]</td>
<td>0</td>
<td>4</td>
<td>0</td>
<td>3</td>
</tr>
<tr>
<td>Running costs for electricity * [€/office/year] (≈0.1 €/kWh)</td>
<td>~500 €</td>
<td>~420 €</td>
<td>~190 €</td>
<td>~150 €</td>
</tr>
</tbody>
</table>

Table 2: simulation results based on the input assumptions described in table 1

Using an ideal and worst case scenario reveals a significant range of influence different building use has on thermal and visual comfort, energy consumption and CO\textsubscript{2} emissions in offices. From the case study described above the following results can be derived:

- Ideal building use can reduce energy consumption, CO\textsubscript{2} emissions and running costs for electricity up to 70% compared with the worst case. However, the contribution of single occupants is with up to 15% rather small.
- Ideal building use can reduce peak cooling loads up to 65% compared to the worst case.
- Assuming the applicability of adaptive thermal comfort in mixed mode buildings, cooling set points can be increased by 4K from the worst to the ideal scenario of building use.
while maintaining the same thermal comfort level. This approach would allow for 3-7K
higher cooling set points compared to commonly used set point of 22°C.

- Regarding building use, the key to optimization of thermal comfort, energy consumption,
  CO₂ emissions and running costs is the reduction of internal heat loads. Among these,
  energy saving office equipment has largest optimization potential, followed by energy
  saving lighting systems.
- Active blind and light switching of users increases the percentage of working time with
  full view by 30% without negative impact on thermal comfort. However the positive
  influence on daylight autonomy is smaller.

DISCUSSION AND CONCLUSIONS

From the case study described above the following general conclusions can be drawn:
- The application of adaptive thermal comfort evaluation in mixed mode buildings provides
  the potential for significant reductions in energy consumption and CO₂ emissions. Additionally due to lower of peak loads, cooling systems could be smaller dimensioned.
- Energy conscious building use on company level (choice of lighting and office
  equipment) can contribute significantly to a reduction of overheating, energy
  consumption and CO₂ emissions.
- The influence of building use by single occupants on thermal comfort and CO₂ emissions
  is predefined by, and not as strong as on a company level.
- In mixed mode buildings with manually operated blinds and lights, visual comfort only
  depends upon individual occupants. Active users can increase both, daylight autonomy
  and quantity of view at the same time.
- CO₂ emissions are most efficiently reduced by optimising parameters of building use with
  low coefficient of performance and at the same time high primary energy factor.
- An ideal and worst case scenario for building use can help to estimate the variability of
  comfort and energy performance in real buildings, and indicate optimisation potential.

ACKNOWLEDGEMENT

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