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Challenges of Non-domestic Building Retrofit Optimisation by Using Dynamic Performance Modelling

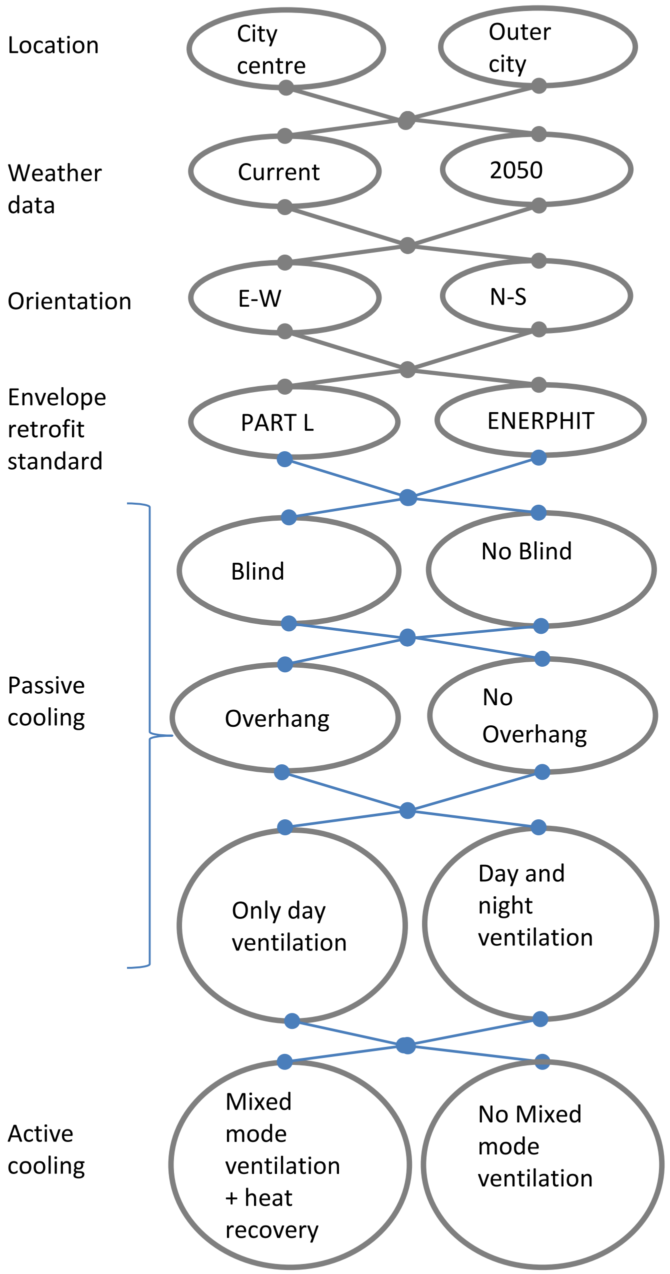
# Evaluation of Retrofit Strategies for Post-war Office Buildings

## Samples of Post-war Office Buildings


Harvest House Offices, Portsmouth
Built in 1960 , Architect: Slater & Havard

Edinburgh University Arts Faculty
Built in 1967, Listed Grade II

Carr & Co Offices, Birmingham
Built in 1960, Architect: Ernö Goldfinger

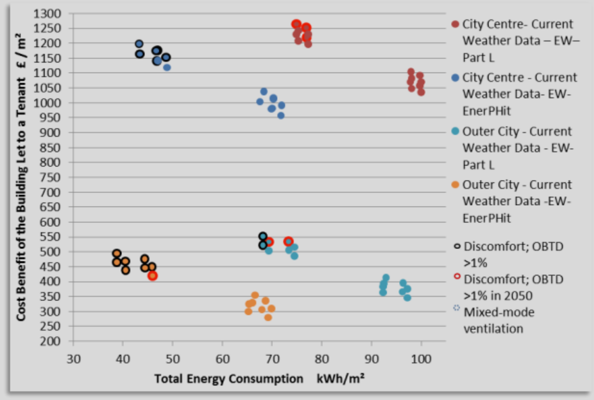


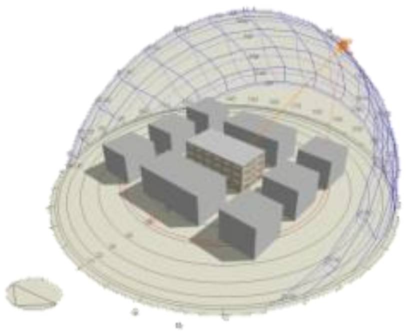

The project aimed to evaluate the retrofit decision making process of post-war office buildings (1945-1980) by applying dynamic energy simulations to representative building models in order to create a guidance optimising

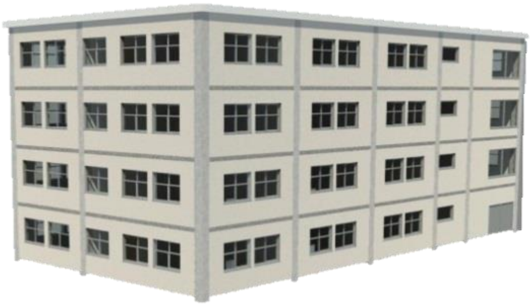
- energy efficiency,
- overheating risk,
- thermal discomfort and
- sophisticated cost estimations.

By comparing

- various orientations
- Part L vs EnerPHit,
- 2015 vs 2050
- Passive vs Active Cooling
- City centre vs Other city conditions





- High energy consumption
- Unregulated toxic materials
- Thermal discomfort
- Aesthetical problems

## 1# Building level comfort

There is no agreement in literature on how to asses building level discomfort.

Simulation programs can produce hourly zonal comfort outputs according to a chosen set of criteria. However, to be able to compare retrofit combinations, the overall discomfort of a whole building, rather than a single zone, is needed. In the literature there is no clear agreement on how to calculate such a value. To find building level thermal discomfort, overall building thermal discomfort (OBTD), a new approach was suggested using CEN 15251; the CIBSE criteria was taken as a starting point and Criterion 1 was enriched by including the number of occupants who were affected by the overheating,

CIBSE Criterion 1 was enriched by taking number of occupants affected by overheating into account; overall building thermal discomfort (OBTD).

$$\mathrm{OBTD} = \frac{1}{T}\sum_{t=1}^{T} \frac{\sum_{z=1}^{Z}(\mathrm{NPz,t \ x \ Dz,t})}{\mathrm{NPt}} \ x\ 100 \quad \% < 1\%$$

Where:
NPz,t = number of people in zone (z) at time (t)
Dz,t = whether the operative temperature exceeds the comfort threshold in zone (z) at time (t) or not, i.e.
Dz,t = 0 if the threshold is not exceeded or 1 if it is
NPt = total number of people in the building at the time (t)
T = total number of occupied hours
Z = total number of zones in the building

Further discussion is needed about the allowable percentage discomfort. The determination of building level thermal discomfort assessment protocol could be very important when other’s conduct similar parametric studies.

## 2# Overall cost calculation

The central dilemma is that, following building retrofit the occupier benefits the energy cost savings, whereas the investor pays for the cost of the retrofit.

CBO = the NPV of the cost benefit of the energy reduction + the NPV of the productivity benefits – Investment costs

CBT = the NPV of the rent increase – Investment costs

The cost benefit of the retrofit when the building is used by the owner (CBO) calculated by subtracting investment costs from the sum of the Net Present of the energy cost benefit and productivity benefit.

In constant, when office buildings are let to tenants (CBT), the owners only benefit from a potential rent increase. Thus, the calculation was done by subtracting investment from the NPV of rent increase.

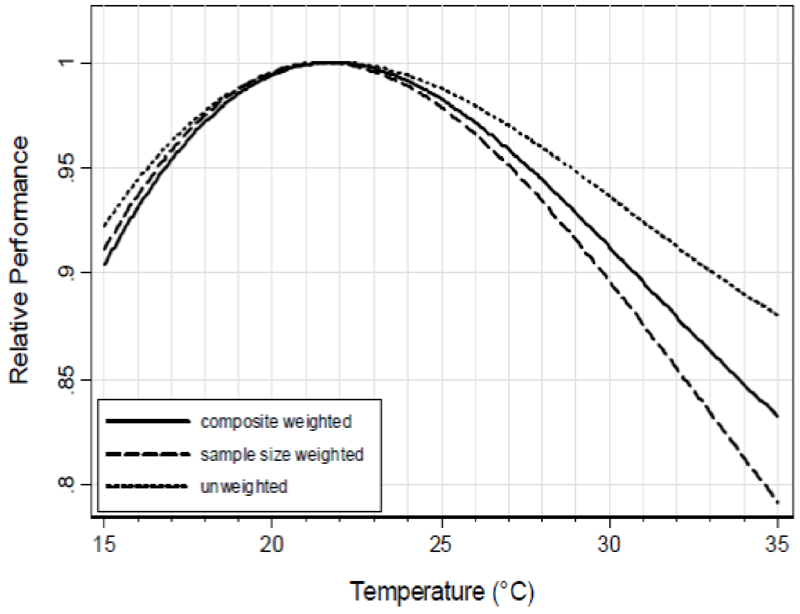
In Germany, for example, landlords have been entitled to increase the rent by 11 % of the retrofit investment costs since 2011 (BGB 2017). In California, annual rent increase due “to major capital improvement” is limited to 10 % of the yearly paid rent until the improvement has been paid off (SFTU 2017). However, when there is a lack of regulation, rent increase may not be possible.

In the UK there is no regulation which entitles building owners to increase the rent of a retrofitted building. Regulations need to be updated providing a secure benefit for the building owners.

## 3# Productivity costs

The most difficult part of the cost estimation for productivity, primarily because of its inherent subjectivity and the little empirical work undertaken in the area.

The calculation was made by finding the difference in productivity costs in comparison with the base-cases without any retrofit. The relation of indoor air temperature to relative productivity is given by the equation by Seppanen et al.




Net present value of cost benefit as a result of improved indoor temperatures hence productivity were added to the cost calculations.

PC=NPV(RPC retrofit case - RPC basecase )/TFA

$$RPC=\sum_{z=1}^{Z}\sum_{t=1}^{T}(1-\mathrm{RP})\ \mathrm{x}\ \mathrm{NPz},t\ \mathrm{x}\ \mathrm{HPR}$$

$$RP = 0.1647524Ta - 0.0058274Ta^2 + 0.0000623Ta^3 - 0.4685328$$

Where:

RP = relative productivity, which is the ratio of relative performance to indoor air temperature (Ta)

Where:

RPC= the relative productivity cost, which is found by subtracting RP from one and then multiplying by the number of people (NP) in a zone (z) at a time (t) and their average salary for this time period. Then this value was summed of for all times (T) and all zones (Z).

HPR = hourly pay rate, in this research a fixed value was used for all occupants.

PC = the productivity cost benefit of the retrofit is given by the change in RPC relative to the base-case per total floor area of the building (TFA). Then, the net present value (NPV) was applied for the period of 2016 to 2050.

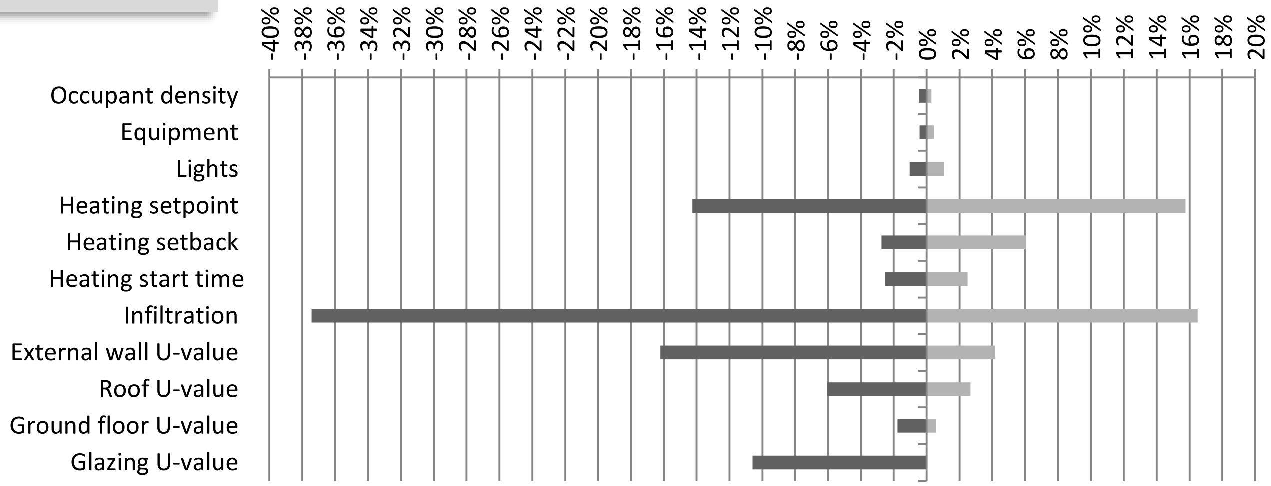
Other measurement studies, based on operative temperature, are necessary and the correlation of the productivity to the adaptive comfort standards needs to be determined.

## 4# Uncertainty

A parametric Exemplar project involves significant level of uncertainty due to lack of required measurements. Also the predictions of the future conditions, especially the future weather conditions increase the uncertainty dramatically.

Bringing the individual SA results together enables the sensitivity of the total annual energy consumption to changes in each input to be compared. The maximum and minimum values and intervals of each variable are listed.

Sensitivity Analysis was run to identify the most important parameters in relation to building performance and to focus design and optimization on these fewer, but most important, parameters.




Further research might include a full global sensitivity analysis spanning the full range of possible rates and higher order effects, to overcome the limitations which could have a strong influence on cost calculations.

**THANK YOU**