Welcome to YEPG
Rethinking Energy Performance

Simulation:
Are we just ticking boxes?
To become an official member of the group - please email groups@cibse.org stating that you would like to join the Young Energy Performance Group.
6.30pm Welcome
6.35pm Our Speakers
7.30pm Discussion
Networking & Drinks
Rokia Raslan (UCL)

Roger Smith (Parsons Brinckerhoff)

Greig Paterson– Bartlett UCL / Aedas
Rokia Raslan
UCL
SIMULATION: ARE WE JUST TICKING BOXES?

Assessing Building Energy Assessment

Rokia Raslan
Complex Built Environment Systems
Bartlett School of Graduate Studies
University College London
I’m only doing this for the compliance paperwork
• The demand for building assessment results is becoming commonplace in the feedback for energy efficient design.

• May occur throughout the building’s lifecycle.

• Increasingly integrated into the planning application process at local or city government level.

Simulation for Building Assessment
Simulation for Building Assessment: Regulations & Ratings

LEED
BREEAM
CASBEE
Pearl Estidama
Green Star
SICES
Green Globes
Haute Qualité Environnementale

Status of Development/Enforcement:
- Mandatory/Developed
- Mixed and/or Voluntary
- Proposed
- Unknown/None
Simulation for Building Assessment: General Approach

**Process**

1. Create Proposed Building
2. Generate Notional Equivalent/ Baseline
3. Calculate Benchmarks
4. Compare
5. Determine Compliance/ Assess Certification/Scheme Rating

**Outputs**

- **Building Regulations**
  - Pass
  - Fail

- **Building Regulations Compliance**
  - A: Good
  - G: Excellent

- **Building Regulations Certification**
  - Sustainability Assessment/Rating
Warning!

*Remember:* No computational model will ever be fully verified, guaranteeing 100% error-free implementation

......But is it valid?
Case Study 1:
Simulation for Building Regulations
In the UK:

*In accordance with the requirements stated in Article 3 of the EPBD, the National Calculation Methodology (NCM) was defined by the ODPM as the unified calculation-based methodology for the demonstration of compliance.*
Case Study 1: The Test

Method

**12 Accredited Tools**

SBEM
9 FI-SBEMs
1 DSM/FI-SBEM
1 DSM

**Single Modeller**

Relevant Qualifications + Experience

**Minimal external tools**

AutoCAD & PVSYST v4.33

**Test Model(s)**

3 Typical Non-domestic Variants

Source: Raslan & Davies (2009)
Case Study 1: Model Interpretation Results

DEGREE OF DETAIL

Non-Graphical Model
Simplified 2D Floor Plan
2D Floor Plan/3D Zone Display
Abstract 3D Model
Detailed 3D Model

Variant 1
Variant 2
Variant 3

Source: Raslan & Davies (2009)
**Case Study 1: Results**

**CO₂ Emissions:** \( \text{TER} = C_{\text{NOT}} \times (1 - \text{improvement factor}) \times (1 - \text{LZC benchmark}) \)

<table>
<thead>
<tr>
<th>Variant 1: Shallow Plan Office Building</th>
<th>Tool</th>
<th>Emissions (kgCO₂/m². annum)</th>
<th>BER Improvement %</th>
</tr>
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<tbody>
<tr>
<td></td>
<td></td>
<td>Notional</td>
<td>TER</td>
</tr>
<tr>
<td>A</td>
<td></td>
<td>75.3</td>
<td>54.2</td>
</tr>
<tr>
<td>B</td>
<td></td>
<td>72.9</td>
<td>52.5</td>
</tr>
<tr>
<td>C</td>
<td></td>
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<td>50.4</td>
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<td>D</td>
<td></td>
<td>89.3</td>
<td>64.3</td>
</tr>
<tr>
<td>E</td>
<td></td>
<td>108.6</td>
<td>78.2</td>
</tr>
<tr>
<td>F</td>
<td></td>
<td>88.8</td>
<td>63.9</td>
</tr>
<tr>
<td>G</td>
<td></td>
<td>88.8</td>
<td>63.9</td>
</tr>
<tr>
<td>H</td>
<td></td>
<td>88.9</td>
<td>64</td>
</tr>
<tr>
<td>I</td>
<td></td>
<td>73.4</td>
<td>52.8</td>
</tr>
<tr>
<td>J</td>
<td></td>
<td>89.4</td>
<td>64.4</td>
</tr>
<tr>
<td>K</td>
<td></td>
<td>89.5</td>
<td>64.5</td>
</tr>
<tr>
<td>L</td>
<td></td>
<td>43.6</td>
<td>31.4</td>
</tr>
<tr>
<td>M</td>
<td></td>
<td>52.2</td>
<td>37.6</td>
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</table>

**Average**

<table>
<thead>
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<th>Emissions</th>
<th>BER Improvement %</th>
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<tr>
<td></td>
<td>79.3</td>
<td>57.1</td>
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</table>

**Standard Deviation**

<table>
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<th>Emissions</th>
<th>BER Improvement %</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>17.4</td>
<td>12.5</td>
</tr>
</tbody>
</table>

Source: Raslan & Davies (2009)
### Case Study 1: Results

**CO₂ Emissions:** \( \text{TER} = C_{\text{NOT}} \times (1 - \text{improvement factor}) \times (1 - \text{LZC benchmark}) \)

#### Variant 2: Deep Plan High Rise Office Building

<table>
<thead>
<tr>
<th>Tool</th>
<th>Emissions (kgCO₂/m².annum)</th>
<th>BER Improvement %</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>Notional TER BER Pass/Fail</td>
<td>Notional TER</td>
</tr>
<tr>
<td>A</td>
<td>74.6 53.7 13.2 Pass 82%</td>
<td>75%</td>
</tr>
<tr>
<td>B</td>
<td>74.6 53.7 29.6 Pass 60%</td>
<td>45%</td>
</tr>
<tr>
<td>C</td>
<td>73.5 52.9 34.4 Pass 53%</td>
<td>35%</td>
</tr>
<tr>
<td>D</td>
<td>86.9 62.6 22 Pass 75%</td>
<td>65%</td>
</tr>
<tr>
<td>E</td>
<td>96.5 69.5 36.8 Pass 62%</td>
<td>47%</td>
</tr>
<tr>
<td>F</td>
<td>86.6 62.3 28.2 Pass 67%</td>
<td>55%</td>
</tr>
<tr>
<td>G</td>
<td>84.7 61 28.5 Pass 66%</td>
<td>53%</td>
</tr>
<tr>
<td>H</td>
<td>86.8 62.5 51.8 Pass 40%</td>
<td>17%</td>
</tr>
<tr>
<td>I</td>
<td>76.2 54.8 42.3 Pass 44%</td>
<td>23%</td>
</tr>
<tr>
<td>J</td>
<td>98.7 71.1 62.2 Pass 37%</td>
<td>13%</td>
</tr>
<tr>
<td>K</td>
<td>87.4 62.9 32.7 Pass 63%</td>
<td>48%</td>
</tr>
<tr>
<td>L</td>
<td>53.1 38.2 26.1 Pass 51%</td>
<td>32%</td>
</tr>
<tr>
<td>M</td>
<td>38.8 27.9 19.5 Pass 50%</td>
<td>30%</td>
</tr>
<tr>
<td>Average</td>
<td>78.3 56.4 32.9</td>
<td></td>
</tr>
</tbody>
</table>

**100% Pass Rate**

### Source:
Raslan & Davies (2009)
### CO₂ Emissions: TER = C\textsubscript{NOT} x (1- improvement factor) x (1- LZC benchmark)

#### Variant 3: Retail Shed

<table>
<thead>
<tr>
<th>Tool</th>
<th>Emissions (kg\textsubscript{CO₂}/m\textsuperscript{2}.annum)</th>
<th>BER Improvement %</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>Notional</td>
<td>TER</td>
</tr>
<tr>
<td>A</td>
<td>170.5</td>
<td>122.7</td>
</tr>
<tr>
<td>B</td>
<td>108.1</td>
<td>77.9</td>
</tr>
<tr>
<td>C</td>
<td>170.2</td>
<td>122.5</td>
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<tr>
<td>D</td>
<td>157.6</td>
<td>113.5</td>
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<tr>
<td>E</td>
<td>165.4</td>
<td>119.1</td>
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<tr>
<td>F</td>
<td>162.3</td>
<td>116.8</td>
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<td>76.7</td>
</tr>
<tr>
<td>K</td>
<td>150.5</td>
<td>108.4</td>
</tr>
<tr>
<td>L</td>
<td>93.3</td>
<td>67.2</td>
</tr>
<tr>
<td>M</td>
<td>77.2</td>
<td>55.7</td>
</tr>
</tbody>
</table>

| Average | 142.8 | 102.8 | 90.9 |
| Standard Deviation | 33.5 | 24.1 | 28.2 |

Source: Raslan & Davies (2009)
### Case Study 1: Findings

1. Limitations in the scope of applicability of accredited tools
2. A lack of input data standardisation
3. Variability between tool results

<table>
<thead>
<tr>
<th>Parameter</th>
<th>Expected results</th>
<th>Actual results</th>
</tr>
</thead>
<tbody>
<tr>
<td><strong>CO₂ Emissions</strong></td>
<td>Concurrence/close similarity between NOT, TER &amp; BER within same tool class</td>
<td>Significant variations both between &amp; within tool groups for all benchmark figures</td>
</tr>
<tr>
<td></td>
<td>Similarity between results of SBEM &amp; FI-SBEMs</td>
<td>Inconsistencies &amp; significantly lower predictions for DSMs</td>
</tr>
<tr>
<td></td>
<td><strong>Uniformity in Pass/Fail result for each variant</strong></td>
<td><strong>Inconsistency in Pass/Fail result for each variant</strong></td>
</tr>
<tr>
<td><strong>U-Values</strong></td>
<td>Consistent calculated area weighted &amp; individual U-Values for all tools</td>
<td>Inconsistencies between calculated area weighted &amp; individual U-Values for all tools</td>
</tr>
<tr>
<td><strong>HVAC Systems Performance</strong></td>
<td>Similarity in annual energy demand &amp; consumption for the ACT &amp; NOT within same tool class</td>
<td>A large degree of variability for both the ACT &amp; NOT</td>
</tr>
</tbody>
</table>
Case Study 1: Implications?

Carbon Targets

- Building Regulations E&W 2005/6

Case Study 1: Implications?

Carbon Targets

- Building Regulations E&W 2005/6

**Case Study 1: Implications?**

**EPCs:** Minimum building standards: all buildings to achieve at least an F-rated EPC by 2020

<table>
<thead>
<tr>
<th>Energy Certificates</th>
<th>Non Domestic EPC</th>
<th>Display Energy Certificate</th>
</tr>
</thead>
<tbody>
<tr>
<td>Total Lodgements</td>
<td>154296</td>
<td>47368</td>
</tr>
</tbody>
</table>
Case Study 2:
Building Ratings Systems
Simulation Tools
Case Study 2: LEED & BREEAM

Comparative Weightings

Energy is most important!

Source: Clarke(2009) BREEAM on the international stage.
BREEAM: Energy New Construction

Ene - 01 (15 Credits)

• Rating benchmark is the EPR-NC (Energy Performance Ratio for New Constructions).

• Calculated using data from three parameters:
  • Operational energy demand (notional/actual)
  • Energy consumption (notional/actual)
  • Total resulting CO2 emissions (notional/actual)
Case Study 2: The Test

Method

3 Accredited Tools

Tas
IES
EnergyPlus

Single Modeller

Relevant Qualifications + Experience

Test Model(s)

A single non-domestic high-rise case study

Source: Schwartz & Raslan (2013)
BREEAM: Ene - 01 Score

EPR-NC components in the ‘Designed’ & ‘Notional’ buildings

<table>
<thead>
<tr>
<th>Tool</th>
<th>EPR-NC</th>
<th>Ene-01 Score Gained</th>
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</thead>
<tbody>
<tr>
<td>Tas</td>
<td>0.37</td>
<td>6</td>
</tr>
<tr>
<td>EnergyPlus</td>
<td>0.39</td>
<td>7</td>
</tr>
<tr>
<td>IES</td>
<td>0.44</td>
<td>7</td>
</tr>
</tbody>
</table>

Source: Schwartz & Raslan (2013)
The Issue of Validity

• Modelling for assessment is in many cases considered a “tick box exercise”
• Not part of or integrated in the design process
• Defeats the purpose
• The Performance Gap!

What’s next?

• Beyond inter-model comparative assessment
Thank You
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Roger Smith
Parsons Brinckerhoff
SIMULATION – ARE WE JUST TICKING THE BOXES?

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07919 306576 (mobile)
smithrog@pbworld.com
www.pbworld.com
TYPES OF MODELLING AND THEIR APPLICATIONS

Dynamic Thermal
- Overheating Analysis
- Energy Consumption Analysis
- Energy Strategy Reports for Planning

Steady State Thermal
- Main Plant Sizing
- Terminal Unit Sizing
- DEC

Compliance
- Part L
- EPC
- DEC
TYPES OF MODELLING AND THEIR APPLICATIONS

Lighting
- Daylighting
- Glare Analysis
- Lighting levels

CFD
- Temperature Distribution
- Internal Airflow Patterns
- External Air Paths
Embankment Transformer Sub-station - Overview

Project description

Natural ventilation analysis of existing substation buildings

Services provided

- Mechanical services engineering
- CFD air flow and Natural Ventilation analysis
Embarkment Transformer Sub-station – Initial Study Geometry
Embarkment Transformer Sub-station – Initial Study Results

USING SIMULATION TO DRIVE DESIGN – Case Study: London Underground
Using Simulation to Drive Design –
Case Study: London Underground

Embankment Transformer Sub-station – Follow Up Study Geometry
Embankment Transformer Sub-station – Results
Embankment Transformer Sub-station – Results
Back to Basics

Admittance Calculations
- Building Fabric Materials
- External Temperature
- kW Cooling Load Peak & 24hr RMS

Nat Vent Calculations
- Equipment Heat Gains
- m² Louvre Area

Required Louvre Area
- Nat Vent
- CFD
- Mech Vent

\[ \Phi_k = \Phi_a + \Phi_d + \Phi_{sg} + \Phi_v \]
ABOVE AND BEYOND THE NORM: INTEGRATING SIMULATION WITH POST PROCESSING—
Case Study: London Fire Brigade

Proposed Primary Training Venue

Project description

Preliminary planning design of new training centre.

Building physics contribution

- Dynamic thermal analysis of building
- Part L Analysis
- Concept design development
- Dynamic energy and CO2 analysis
Planners require an assessment of the energy usage of the building in order to demonstrate compliance with Building Regulations and local offsetting requirements. In order to determine meaningful results it is vital to simulate the usage patterns of the building as accurately as possible.
### Proposed Primary Training Venue – Planning Energy Statement

<table>
<thead>
<tr>
<th></th>
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<th></th>
<th></th>
<th></th>
<th></th>
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</tr>
</thead>
<tbody>
<tr>
<td>Classroom</td>
<td>11</td>
<td>22</td>
<td>154</td>
<td>667</td>
<td>8008</td>
<td>7</td>
<td>52</td>
<td>227</td>
<td>2721</td>
<td>34%</td>
<td>34%</td>
<td>34%</td>
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<td>Syndicate room</td>
<td>2</td>
<td>4</td>
<td>28</td>
<td>121</td>
<td>1456</td>
<td>1</td>
<td>4</td>
<td>16</td>
<td>197</td>
<td>13%</td>
<td>14%</td>
<td>14%</td>
<td>14%</td>
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<td>IEC</td>
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<td>8</td>
<td>56</td>
<td>243</td>
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<td>4</td>
<td>27</td>
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<td>61</td>
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<td>8</td>
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<td>60%</td>
<td>60%</td>
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<td>Hazmat</td>
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<td>2</td>
<td>14</td>
<td>61</td>
<td>728</td>
<td>0</td>
<td>2</td>
<td>8</td>
<td>98</td>
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<td>13%</td>
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<td>13%</td>
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<tr>
<td>FRU/RTC</td>
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<td>2</td>
<td>14</td>
<td>61</td>
<td>728</td>
<td>1</td>
<td>7</td>
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<td>368</td>
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<td>51%</td>
<td>51%</td>
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<td>303</td>
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<td>681</td>
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<td>2</td>
<td>14</td>
<td>61</td>
<td>728</td>
<td>0</td>
<td>1</td>
<td>3</td>
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<td>N/A</td>
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<td>41</td>
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<td>4%</td>
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<td>42</td>
<td>163</td>
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<td>13%</td>
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<td>13%</td>
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<td>N/A</td>
<td>N/A</td>
<td>N/A</td>
<td>N/A</td>
<td>3</td>
<td>19</td>
<td>84</td>
<td>1009</td>
<td>13%</td>
<td>13%</td>
<td>13%</td>
<td>13%</td>
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<tr>
<td>Control room</td>
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<td>4</td>
<td>28</td>
<td>121</td>
<td>1456</td>
<td>1</td>
<td>4</td>
<td>16</td>
<td>186</td>
<td>13%</td>
<td>13%</td>
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<td>13%</td>
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<tr>
<td>Lecture Theatre</td>
<td>3</td>
<td>6</td>
<td>42</td>
<td>182</td>
<td>2184</td>
<td>0</td>
<td>2</td>
<td>7</td>
<td>85</td>
<td>4%</td>
<td>4%</td>
<td>4%</td>
<td>4%</td>
</tr>
</tbody>
</table>

Client provided a training programme for the year. This was analysed and a utilisation figure was determined.

Custom profiles were then created to represent the usage patterns of the building.
ABOVE AND BEYOND THE NORM: INTEGRATING SIMULATION WITH POST PROCESSING
Case Study: London Fire Brigade

Proposed Primary Training Venue – Planning Energy Statement

Catering Loads  
External Lighting  
Lifts  
LPG for Fire Training and smoke treatment
Proposed Primary Training Venue – Planning Energy Statement

<table>
<thead>
<tr>
<th>Source of carbon emissions</th>
<th>Estimated emissions / kgCO$_2$eq/year</th>
</tr>
</thead>
<tbody>
<tr>
<td>Gas space heating (including training areas and accommodation spaces)</td>
<td>83,434</td>
</tr>
<tr>
<td>Elec space heating (including small scale resistance heating to ancillary spaces and heat pump technology to academic areas)</td>
<td>6,489</td>
</tr>
<tr>
<td>Domestic Hot Water Heating</td>
<td>9,468</td>
</tr>
<tr>
<td>Space Cooling (heat pump systems to academic training areas and cooling to computer rooms)</td>
<td>3,613</td>
</tr>
<tr>
<td>Heat rejection fan/pump power</td>
<td>2,168</td>
</tr>
<tr>
<td>Auxiliary energy (including fan and pump power from all system types)</td>
<td>10,489</td>
</tr>
<tr>
<td>DHW pump power (circulation pump energy)</td>
<td>1,811</td>
</tr>
<tr>
<td>Lighting (including all internal zones)</td>
<td>127,012</td>
</tr>
<tr>
<td>General Equipment (inc small power appliances, computers and similar)</td>
<td>27,041</td>
</tr>
<tr>
<td>Catering Gas (consumption in main kitchen area)</td>
<td>2,281</td>
</tr>
<tr>
<td>Catering Elec (consumption in main kitchen area)</td>
<td>9,249</td>
</tr>
<tr>
<td>Lifts (small level of electrical consumption from passenger lift)</td>
<td>362</td>
</tr>
<tr>
<td>External lighting</td>
<td>37,834</td>
</tr>
<tr>
<td>Total</td>
<td>321,250</td>
</tr>
</tbody>
</table>
ABOVE AND BEYOND THE NORM: INTEGRATING SIMULATION WITH POST PROCESSING—Case Study: London Fire Brigade

So what did this achieve?

- Nearly 30% improvement on Part L 2010
- Demonstrated a 15.5% offset of carbon emissions via on-site renewables
- Provided basis for open dialogue with Planning Authority
- Allowed evaluation of design options giving meaningful feedback to design team
IF USED CORRECTLY AND INTELLIGENTLY SIMULATION IS ANYTHING BUT “JUST TICKING THE BOXES”

THANK YOU FOR LISTENING
Greig Paterson
Bartlett UCL / Aedas
Greig Paterson

Developing a *design* tool
EngD at The Bartlett School of Graduate Studies
Sponsored by Aedas R&D (Architects)
Create an early stage design tool that:

- Predicts operational energy consumption
- Integrates into the workflow of architects

Using school design in England as a test case
Environmental Building Design

- Heating energy consumption
- Summertime overheating
- CO₂ emissions
- Daylight
- Lighting load

Greig Paterson YEPG Summer Series
‘Wicked’ problems

- Solving one problem can create another
- No right or wrong, just better or worse
- No global optimum

Diagram showing the balance of heating energy consumption, summertime overheating, CO₂ emissions, daylight, and lighting load.
Design aids *(and experience)* help designers make design decisions.
Design Guidelines

Design Guidelines

Fabric Heat Loss

\[ \text{Fabric Heat Loss} = \text{U Value} \times \text{Area} \times (\text{indoor} - \text{outdoor dry bulb temperature}) \]

**Steady State Calculation Based Methods**

Environmental Design Decision Aids

Design Guidelines

Steady State Calculation Based Methods

Fabric Heat Loss = U Value × Area (eg., external wall) × ΔT (indoor – outdoor dry bulb temperature)

Correlation Based Methods

Environmental Design Decision Aids

Design Guidelines

Physical Modelling

Steady State Calculation Based Methods

Correlation Based Methods

Fabric Heat Loss = 
U Value x Area (eg., external wall) 
\times \Delta T \text{ (indoor – outdoor dry bulb temperature)}

Fabric Heat Loss = U Value x Area (eg., external wall) x ΔT (indoor – outdoor dry bulb temperature)
With regards to energy consumption

Building simulation often offers the most flexibility, due to the unique, wicked nature of building design.

However...

Architects often reject simulation: Simulation often fails to integrate into the workflow of architects
However...

Architects often reject simulation: Simulation often fails to integrate into the workflow of architects

‘Evaluation’ tools rather than ‘design’ tools
Timely process, gathering and inputting data
Data is often prepared after major design decisions have been made

Lawson
However...

Architects often reject simulation: 
*Simulation often fails to integrate into the workflow of architects*

*‘Evaluation’ tools rather than ‘design’ tools*  
*Timely process, gathering and inputting data*  
*Data is often prepared after major design decisions have been made*

*Discrete solutions – omitting ‘in-between’ solutions*  

---

*Lawson  
Pratt et al*
However...

Architects often reject simulation:
*Simulation often fails to integrate into the workflow of architects*

`Evaluation` tools rather than `design` tools

*Timely* process, gathering and inputting *data*
Data is often prepared *after major design decisions* have been made

`Discrete` solutions – omitting *‘in-between’* solutions

`Slow` feedback – minutes to hours for each simulation

`Complexity` – requires specialist training
*Outsourced* to specialist, ~2-4 weeks for feedback

*Lawson*

*Pratt et al*
Source: CarbonBuzz

Performance Gap
Design vs Actual (Schools)

Source: CarbonBuzz
**Performance Gap**

Design vs Actual (*Schools*)

Source: **CarbonBuzz**


Electricity Fuel

Heating Fuel

**Design Data Medians**

**CIBSE TM46 Benchmark**

**Actual Data Medians**

Source: CarbonBuzz [an RIBA CIBSE platform]

The problem with modelling **real** problems is the lack of understanding of mechanisms because of **complex and nonlinear interactions**.

The best solution can be to **learn system behaviour through observations**.  

*Samarasinghe*
Display Energy Certificates are a source of actual ‘observed’ building behaviour.

Artificial neural networks are one method of predicting global behaviour in complex real world problems.
Machine learning technique

The network contains layers of neurons connected by synaptic weights.

Example:

Tumor Evaluation Neural Network

Input Layer
- Area
- Perimeter
- Texture
- Shape

Hidden Layer

Output Layer
- Benign
- Malignant
School design:

Conceptual structure of the feedforward artificial neural network
Artificial Neural Network
Prediction technique

Outputs: Heating or electrical energy consumption

DECs

EuiHtg, EuiElec (kWh/m²/yr)

Conceptual structure of the feedforward artificial neural network

Synaptic weights

Greig Paterson YEPG Summer Series
Artificial Neural Network
Prediction technique

**Inputs:** Design and briefing data

Desktop study

- Geometry
- Fabric
- Site
- Building Systems
- Occupancy

Conceptual structure of the feedforward artificial neural network
Show the network **100s of inputs** and **corresponding outputs** during training

The **weights** are **altered** during the **training** process depending on the accuracy of the network’s predictions

**After training** the aim is to accurately **predict** outputs based on new inputs

---

Conceptual structure of the feedforward artificial neural network

**Matlab Neural Network Toolbox**
Data Collection (Inputs)

Data has been collected on ~600 schools across England

**Collection criteria** (for consistency)
1) Single building
2) Single build age
3) Have a valid DEC

**Collection Techniques**
Digital maps
School websites
Databases (e.g. Department of Education)
Auxiliary DEC data
Examples of data collected

- Floor area
- Internal environmental conditioning type
- Number of pupils
- Compactness ratio

\[ \text{perimeter of building} / \text{perimeter of circle with same area} \]
Examples of data collected

- Roof shape
- Year of construction
- Glazing percentage
- Orientation
User Interface

Design tool

**SEED** School [Early] Environmental Design Tool

![Building Footprint]

- **External Wall Material**: Brickwork
- **Roof Material**: Ceramic Tile

**Annual Energy Consumption**

- **Benchmark for Heating**
- **Benchmark for Electricity**

- **Glazing % North Facing Facades**: 0%
- **Glazing % South Facing Facades**: 0%
- **Glazing % East Facing Facades**: 0%
- **Glazing % West Facing Facades**: 0%

- **Rooflights**: Yes

**Site + Climate** | **Form** | **Fabric** | **Services** | **Social**

*Representation of the user interface*
‘App’ style

Sliders + tick boxes
- Encourage exploration
- Discover ‘in-between’ solutions

Real-time feedback
- Animate results
- Associate relationships between inputs and outputs by acceleration of change in results as design space is explored

Error bars show:
- Neural network accuracy
- Prediction range

Representation of the user interface
‘App’ style

Sliders + tick boxes
- Encourage exploration
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Real-time feedback
- Animate results
- Associate relationships between inputs and outputs by acceleration of change in results as design space is explored

This method does not aim to replace simulation – it aims to offer a quick sanity check for architects at the early design stages . . . allowing them to sketch building performance as well as building form
Based on the test data represented in the eCAADe 2013 paper
465 schools
10% of which used for testing
### Analysis and Findings

#### Prediction Errors

Based on the test data represented in the eCAADe 2013 paper

<table>
<thead>
<tr>
<th>ANN Output</th>
<th>RMSE (kW/m²/yr)</th>
<th>Mean absolute percentage error (%)</th>
</tr>
</thead>
<tbody>
<tr>
<td>Heating energy consumption</td>
<td>30.5</td>
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</tr>
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<td>10.8</td>
<td>19.3</td>
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*Based on the test data represented in the eCAADe 2013 paper*

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### Analysis and Findings

#### Prediction Errors

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</tr>
<tr>
<td><strong>TM46 Benchmark</strong></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Heating energy consumption</td>
<td>41.3</td>
<td>30.5</td>
</tr>
<tr>
<td>Electricity energy consumption</td>
<td>16.7</td>
<td>26.0</td>
</tr>
</tbody>
</table>

*Both methods are based on the test data represented in the eCAADe 2013 paper
465 schools
10% of which used for testing*
Future // On-going Work

- Collect **more inputs**
  - Building services
  - IT equipment
  - Existence of a swimming pool
  - Internal/external catering

- Optimise **neural network** design

- Complete **interface** prototype – begin testing with designers
thank you

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www.bartlett.ucl.ac.uk/graduate
aedasresearch.com

YEPG, 14th August 2013
Our next event is – Retrofits:
Going beyond a face lift?

Register at
cibseyepgsummerseries.eventbrite.co.uk