The integration of building energy system optimisation modelling into the building design process – A Case Study

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Outline Contents

• Systems Thinking
• The TURN model – Introduction
• The TURN model Vs. Building Simulation Models
• The Transport network
• The TURN model Output
• Imperial West case study
• Integration with the RIBA plan of work
• Integration with BIM
• Summary
• References
Systems Thinking

- How the system *functions* and behaves
- How system components *interact* with each other
- How the system *interfaces* with other systems and subsytems

- Well *structured* approach to system development
- Technical and managerial *discipline*
- The V system
Systems Thinking – The V System

Source: Shamieh, 2011
# TURN Model Vs Building Simulation Models

<table>
<thead>
<tr>
<th></th>
<th>TURN Model</th>
<th>Building Simulation Model</th>
</tr>
</thead>
<tbody>
<tr>
<td><strong>System Level</strong></td>
<td>High level – integrated system</td>
<td>Detailed - Sub-systems</td>
</tr>
<tr>
<td><strong>Inputs</strong></td>
<td>Demand profiles, equipment properties, costs and distances between buildings</td>
<td>Building properties, geometry, solar irradiance. Wind speed etc</td>
</tr>
<tr>
<td><strong>Outputs</strong></td>
<td>Optimised energy and site wide services strategy (performance, cost, CO2 and distribution)</td>
<td>Building regulation compliance, control strategy, demand and load profiles</td>
</tr>
<tr>
<td><strong>Primary target design stage</strong></td>
<td>Scoping</td>
<td>Detailed design</td>
</tr>
</tbody>
</table>
The TURN model

• The Technology Urban Resource Network (TURN)

• Energy system optimisation modelling developed for cities or neighbourhoods
  • Mixed Integer Linear Programme (MILP)
  • Originally used to determine energy mix and district energy networks
  • Similar characteristics for large building complexes (smaller scale)

• Integrated Energy System Design
  • Resources (Electricity, heat, gas, emissions)
  • Technologies (Resource conversion, distribution and storage)
  • Modelled as rate of energy transfer
  • Flexible time discretisation
The Model Structure

**Input**
- Spatial description (i.e. size and location of zones)
- Available transport networks
- Building energy demands
- Available technologies
- Associated costs

**Function**
- Mixed-Integer linear programme
- Objective: min. cost or carbon emissions
- Implemented with GAMS

**Output**
- Location of energy conversion technologies (CHP, heat pump etc)
- Transport network structure and energy flows
- Estimated costs, energy and carbon consumption
Transport Network

Source: Samsatli, Keirstead & Shah, 2011
TURN Model Output

(a) Interval 1: 7am to 9am

Source: Samsatli et al, 2011
TURN Model Output

(b) Interval 5: 6pm to 10pm

Source: Samsatli et al, 2011
Imperial West case study

- The Imperial West campus
  - Mixed use development
    - Offices
    - Student accommodation
    - Further education
    - Hotel
    - Residential
- The energy strategy
  - Developed by Hoare Lea
  - 500-700kWe total CHP capacity
  - Located in building C energy centre
  - Cascading district heating network
The Building TURN model inputs

- Energy Demands
  - Hourly data
    - Heating, cooling and electricity
- Time Periods
  - Peak and average (seasonal)
- Spatial Data
  - Building location
- Transport Network
  - Electricity
  - Gas
  - District Heat
  - Conversion rates
- Conversion Technologies
  - CHP, gas boilers, ASHP, GHSP, electric heating, air cooled chillers
  - Capital cost, maintenance costs, operating costs, conversion rates
The Building TURN model output

- The optimum solution
  - Tight termination criteria
  - CHP located close to demand (spread out over the campus)
  - CHP supplemented with gas boilers
  - Air cooled chillers for cooling

Source: Baldock, 2014
Comparisons with the energy strategy

- 3 No. 250 kWe CHP
- Cascading Network
- 30% less time taken to develop Energy Strategy

Source: Hoare Lea, 2011
Energy System Schematic

Source: Samsatli et al, 2011
Integration with the RIBA plan of work

Source: Baldock, 2014
Integration with BIM

Source: Baldock, 2014
Remember the V System......?

Source: Shamieh, 2011
Summary

- Optimised and integrated energy supply strategy, continuously tested
- Validation of energy sub-system (total cost, distribution, equipment, emissions)
- Feedback at each stage of the design process
- Greater understanding of the impact of changes on the energy system
- Time/Cost saving (estimated 30% quicker than standard industry practice)
References


