Occupant's Household Energy Behaviour and Conservation Strategies in a High-Rise Residential Building in Toronto, Canada

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Agenda

• Introduction to MURBs in Toronto
  – Toronto’s Tower Renewal Project
• Energy Conservation and Engagement Strategies
  – Overview
  – MURBs Survey and its Impact
  – Similar Study
• Conclusion
• Questions
Introduction to MURBs in Toronto

• Second highest number of MURBs in North America
  – 1892 MURBs in City of Toronto

• 50% of the city’s total residential building stock

• MURBs were constructed between 1945-1980 as part of the rapid urbanization during post-war period

• From 1990 to 2008, ↑GHGs and ↑secondary energy consumption

• Residential sector - 17% of Canada’s total energy use
The Problem with MURBs

• About 800 of Toronto’s MURBs are privately owned rental properties.

• Today, most MURBs have severely degraded due to lack of maintenance.

• Performance is poor.
  – Concrete frames, aging appliances, little maintenance performed, non-operational building envelopes.
Toronto’s Tower Renewal Project

- Building Consumption Data Analysis and Energy Benchmarking
- Building Simulation and Modelling
- MURBs Sustainability Best Practice Guide
- Tenant Engagement and Behavioural Patterns
- Indoor Environment
- Retrofit Strategies Analysis

OBJECTIVES
- Assess strategies for optimal energy efficiency in Toronto's towers – Multi-Unit Residential Buildings (MURBs).
- Develop MURBs Sustainability Best Practice Guide based on different aspects: social-psychological and behavioural aspects, energy simulation, energy labelling and energy benchmarking, indoor environment and building envelope retrofit.
Human behaviour is unpredictable.

“It is not the building that uses energy, people do.”
(Janda, 2011)

- Occupant predictors on household energy consumption
- Examples: National surveys - SHEU, RECS, NEUD
### Overview of Studies Undertaken – Ryerson’s Initiative

1. Understanding the Performance in MURBS
   - Energy Benchmarking
   - Tenant Survey

2. Solutions to achieve energy reductions
   - Building Envelope Retrofits
   - Impact of Implementation of Survey
   - Real-time Feedback Monitoring Platform
Purpose

1. Investigate the effects of energy conservation strategies on occupant’s energy consumption.

2. Implementation of a Household Energy Use survey had any impact on occupant’s household energy use.
Energy Conservation Strategies and Community Engagement

• Networking - environmental groups, workshops and presentations.

• Marketing – commitment, social norms and feedback.

• Informational – posters, brochures and signs.

• Technological – web based tools and monitoring.
1. Study site, Toronto MURB
   – High-rise, ~150 units, 21.37 m²
   – Low income households, located downtown Toronto, and monthly rent
2. Survey Development – 51 questions
3. Survey Distribution and Collection
   – Posters, meetings, and incentives
   – Three Distribution methods: Mail-in, Interviews, and On-line
4. Research Ethics Approval
   – Ryerson University’s policies
   – Confidentiality
Survey Results

• 36% response rate
  – 37 mail-in, 12 interviews, and 0 on-line

• Demographical Distribution
  – Gender: 80% males
  – Age: 31% over the age of 60
  – Residency: 45% lived in the MURB more than 7 years
  – Grown up: 45% have grown up in Africa
  – Hours per day: 49% spend 9 to 13 hours per day in their unit
  – Income: 37% between $15,000 and $29,999; none over $50,000
Evaluating the Impact of the Survey

- **Method #1**: Comparison of the actual energy consumption before (May to September 2011) and after the survey (May to September 2012). This method just compares energy consumption and does not take into consideration weather conditions (no weather normalization).

- **Method #2**: Creation of an Artificial Neural Network (ANN) model before the survey - Comparison between ANN Predicted Values and Actual Consumption (weather normalized).

<table>
<thead>
<tr>
<th>Date</th>
<th>Activity</th>
</tr>
</thead>
<tbody>
<tr>
<td>October 2010</td>
<td>Start of Energy Consumption Data</td>
</tr>
<tr>
<td>April - May 2012</td>
<td>Implementation of Survey</td>
</tr>
<tr>
<td></td>
<td>Time period between before survey and after survey - April to May 2012</td>
</tr>
<tr>
<td>September 2012</td>
<td>End of Energy Consumption Data</td>
</tr>
</tbody>
</table>
Method #1: Comparison of the actual energy consumption before (May to September 2011) and after the survey (May to September 2012).

- No weather normalization

<table>
<thead>
<tr>
<th></th>
<th>Total energy consumption before the Survey (2011)</th>
<th>Total energy consumption after the Survey (2012)</th>
</tr>
</thead>
<tbody>
<tr>
<td>May</td>
<td>6951</td>
<td>5540</td>
</tr>
<tr>
<td>June</td>
<td>6134</td>
<td>5691</td>
</tr>
<tr>
<td>July</td>
<td>6797</td>
<td>6691</td>
</tr>
<tr>
<td>August</td>
<td>6838</td>
<td>6272</td>
</tr>
<tr>
<td>September</td>
<td>6333</td>
<td>6103</td>
</tr>
<tr>
<td>Sum of energy consumption:</td>
<td>33054</td>
<td>30299</td>
</tr>
<tr>
<td>Difference between before and after survey (kWh):</td>
<td>- 2754</td>
<td></td>
</tr>
<tr>
<td>Percentage difference:</td>
<td>-8.3%</td>
<td></td>
</tr>
</tbody>
</table>
Method #2: Comparison between Predicted to Actual Energy Consumption

- Using ANN Approach
- Weather normalized
  - Creation of a Before Survey Model – using data from October 2010 to March 2012
  - Using this model, predict what the energy consumption would be for May to September 2012.
  - Calculate the percent difference between actual and predicted.

<table>
<thead>
<tr>
<th>If Actual &gt; Predicted</th>
<th>Then: The survey had <strong>NO effect</strong>.</th>
</tr>
</thead>
<tbody>
<tr>
<td>If Predicted &lt; Actual</td>
<td>Then: The survey had <strong>an effect</strong>.</td>
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</table>
Artificial Neural Network (ANN) Approach

- Bottom-up modelling technique → Residential energy consumption
  - Concept: McCulloch and Pitts in 1943
  - Similar approach as Aydinalp et al. (2003)
  1. Model and estimate occupant’s household energy use
  2. Outperform other energy modeling techniques (e.g., Conditional Demand Analysis - CDA)
  3. Determine causal relationships between variables
- Software: Alyuda NeuroIntelligence Version 2.2
ANN Approach cont’d...

Sources of Data

I. Survey data – 48 surveys (Roque et al., 2012)
II. Toronto’s weather conditions – Environment Canada
III. Monthly energy consumption from October 2010 to September 2012 – Toronto MURBs sub-meters

Development of the Network Dataset

– Inputs and Outputs
– 1152 cases – 48 surveys plus 24 months of monthly energy consumption data
Method #2: Results

- ANN approach was used; similar to analyzing survey results (weather normalized).
- Reduction in energy consumption by 6.3%

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<tbody>
<tr>
<td>32329</td>
<td>30299</td>
<td>+2030</td>
<td>+ 6.3%</td>
<td></td>
</tr>
</tbody>
</table>
## Feedback Monitoring Platform (Trinh et al., 2013)

<table>
<thead>
<tr>
<th>Groups</th>
<th>Description</th>
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</thead>
<tbody>
<tr>
<td>Basic feedback (12 participants)</td>
<td>Measure power consumption and air temperature output. Measure suite-level power consumption. Tablet with dashboard application.</td>
</tr>
<tr>
<td>Basic feedback + Social Comparison (12 participants)</td>
<td>Website application displaying unit’s consumption as well as other tenant’s consumption.</td>
</tr>
<tr>
<td>No feedback (106 control condition)</td>
<td>Does not receive any type of feedback.</td>
</tr>
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</table>
Feedback Results

- The average actual savings percentage between the two feedback groups was 10.6% compared to an increased use of 2.3% for those outside the study.
Conclusions

• Understanding of MURBs in Toronto
  – Conducting a household energy use survey in a MURB

• Solutions to achieve reduction in energy consumption
  – Implementation of various strategies
    • Surveys and feedback monitoring

• Future Works
  – Alsaadani et al. (2016)
Acknowledgements

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Thank you for listening to my presentation!
END OF PRESENTATION!!!!!