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Planner Agents: A toolkit for support planning a low carbon urban form
(A preliminary research)

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1 INTRODUCTION
Land use pattern (urban form),

- or land use layout, is a key part of physical plan (master or detailed)
  - Spatial distribution of land use and density
  - Hard to predict by a planning support system (PSS)
  - Proxy of carbon emission and energy consumption

- Land use pattern scenario analysis (LUPSA) – most are parcel-based
  - CUF (Landis 1994)
  - What if? (Klosterman 1999)
  - INDEX (Allen 2001)
  - iCity (Stevens et al. 2007)
  - Other papers regarding land use layout optimization
Planners in LUPSA tools

• Less attention was paid on the behavior of urban planners

• Our research question: How do planners compile land use pattern?
  – What are rules (*preferences*)?
  – How to identify these rules?
  – Are these rules varying among planners?
  – Could we develop a PSS for “simulating” land use patterns using the identified rules?
  – Is the pattern associate with low carbon emission?
Figure 1. Seven of the fifty-two mock-ups used in the experiments (the floor tiles are of 20 cm × 20 cm size).
The entropy of LEGO

Crompton, 2012, EPB

Figure 4. LEGO® models: (a) Guggenheim Museum, (b) Hancock Tower, (c) Empire State, (d) Falling Water, (e) Sears Tower, (f) Seattle Needle.
In this research, we will identify planner rules by

- **Questionnaire**
  - What one planner will do

- **Mining plan drawings**
  - What one planner has done
Then we will develop a PSS (Planner Agents), and simulate land use pattern using identified rules.
Ideally and hopefully to

- save planner’s time and promote plan compilation efficiency
- **Support planning a low carbon urban form**
- E.g.
  - A plan area
  - Identified rules of 20 planners
  - Generate 20 patterns in one minute by using Planner Agent
  - The principal investigator chooses a perfect one
  - All 20 planners focus on it and propose the final drawing
  - Planner C’s work associates with low carbon
2 PLANNER AGENTS
Planner types

• Non-spatial planners
  – Infrastructure, transportation
  – Not directly with land use pattern

• Spatial planners
  – Responsible for preparing land use pattern

• Chief planner
  – Confirm the final plan scheme
Spatial planner: the general process

1. Totals in area
   - For each type of land use (e.g. residential, commercial and industrial)
   - From decision makers or forecasted by macro models

2. Constraints
   - Geographical context: slope, eco space
   - Institutional constraints: development restrictions

3. Negotiating with non-spatial planners (factors)
   - Assume planned facilities, roads, city centers, CBD, etc., are ready prior to plan a land use pattern
   - Weight factors

4. Negotiating with citizens (public participation process)
   - Not accounted in our current research
Spatial planner: simplified rules

• The taste (weight) of each land use on factors is different.
• The weight could be calibrated using questionnaire or data mining on existing plan archives (land use with the highest probability would be selected for a parcel).
  – E.g., industrial parcels tend to be located along main transportation network, commercial parcels around amenities.

\[
T = \{t_k | k = 1,2,3, \ldots K \} \tag{1}
\]

\[
F = \{f_i | i = 1,2,3, \ldots I \} \tag{2}
\]

\[
P = \{p_n | n = 1,2,3, \ldots N \} \tag{3}
\]

\[
W = \{w_{ik} | i \in [1,I], k \in [1,K] \} \tag{4}
\]

\[
P_{nk} = \frac{e^{r_k + \Sigma_{i=1}^{I} w_{ik} \times f_i}}{1 + \Sigma_{k=1}^{K-1} e^{r_k + \Sigma_{i=1}^{I} w_{ik} \times f_i'}} \tag{5}
\]

where \( t_k \) is the planned land use type, \( K \) is its number, \( f_i \) is the PIF, \( I \) is its number, parcel, \( N \) is its total amount, \( w_{ik} \) is the weight of \( f_i \) for \( t_k \), \( P_{nk} \) is the probability of \( t_k \), and \( r_k \) is the corresponding constant term.
Formulating comprehensive constraints

Identifying PRs

Introducing independent variables

Establishing the land use pattern

Communication and coordination between SPA 1 and EPAs

Note: the method for formulating land-use pattern 2 is the same as that for land-use pattern 1.

Land use pattern 2 by SPA2

Evaluating land use patterns

Land use pattern 3 by SPA3

 SPA1

SPA2

SPA3

Existing plan archives

Questionnaire survey

Real model

Virtual reality test

Special knowledge

Land use pattern 1

Special plan 1

Special plan 2

Special plan 3

NPA2

NPA1

NPA3

Local conditions

Comprehensive constraints

Planning rules (requirements and preferences):
- Public facility
- Neighbor
- Natural reserve
- Parcel size, form
- Block
- Subway site

SPA1

Comprehensive constraints

Planning law
Planning guideline
Physical geographic status

Identifying PRs

Introducing independent variables

Establishing the land use pattern

Communication and coordination between SPA 1 and EPAs

Note: the method for formulating land-use pattern 2 is the same as that for land-use pattern 1.
• Land use pattern evaluation
  – Spatial autocorrelation (Moran’s I and LISA)
  – Landscape metrics using FRAGSTATS
  – FEE-MAS model (Long 2011)

• Calculating potential transport energy consumption

Note: the steps, for which the background is gray are considered in this article.
3 BEIJING APPLICATION
• Beijing Detailed Plan (-2020)
• Land use plan in each zone has been exclusively designed by a responsible planner, in 2007
• A perfect data for applying Planner Agents
21 factors
Zone 12 as an example

<table>
<thead>
<tr>
<th>Land use type</th>
<th>Number</th>
<th>Area (km²)</th>
<th>Percentage</th>
</tr>
</thead>
<tbody>
<tr>
<td>R</td>
<td>114</td>
<td>43.85</td>
<td>0.41</td>
</tr>
<tr>
<td>C</td>
<td>97</td>
<td>44.41</td>
<td>0.41</td>
</tr>
<tr>
<td>M</td>
<td>4</td>
<td>0.47</td>
<td>0.004</td>
</tr>
<tr>
<td>O</td>
<td>121</td>
<td>18.94</td>
<td>0.18</td>
</tr>
<tr>
<td><strong>Total</strong></td>
<td><strong>336</strong></td>
<td><strong>107.67</strong></td>
<td><strong>1.00</strong></td>
</tr>
</tbody>
</table>
Constraints

Extracted from Urban Containment Plan of Beijing
See Long et al 2011 for details
Identified rules using multinomial regression

<table>
<thead>
<tr>
<th>Parameter</th>
<th>Weight</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>R</td>
</tr>
<tr>
<td>Intercept</td>
<td>-.70203***</td>
</tr>
<tr>
<td>C21</td>
<td>.59824***</td>
</tr>
<tr>
<td>C22</td>
<td>1.69092***</td>
</tr>
<tr>
<td>C25</td>
<td>.27165***</td>
</tr>
<tr>
<td>C3</td>
<td>.54465***</td>
</tr>
<tr>
<td>C4</td>
<td>.19670**</td>
</tr>
<tr>
<td>C5</td>
<td>1.01238***</td>
</tr>
<tr>
<td>C6</td>
<td>.59667***</td>
</tr>
<tr>
<td>CBD</td>
<td>-.313736***</td>
</tr>
<tr>
<td>Exit</td>
<td>-.77072***</td>
</tr>
<tr>
<td>G</td>
<td>.06680</td>
</tr>
<tr>
<td>Gov</td>
<td>-.22590***</td>
</tr>
<tr>
<td>Hwst</td>
<td>-.08708</td>
</tr>
<tr>
<td>Newcty</td>
<td>-.833651**</td>
</tr>
<tr>
<td>Railst</td>
<td>-.29179**</td>
</tr>
<tr>
<td>Rd06</td>
<td>-.209906***</td>
</tr>
<tr>
<td>Rvr</td>
<td>-.26074***</td>
</tr>
<tr>
<td>Subst</td>
<td>.36312***</td>
</tr>
<tr>
<td>Tam</td>
<td>.52299</td>
</tr>
<tr>
<td>Xzl</td>
<td>.31318***</td>
</tr>
<tr>
<td>Yizhg</td>
<td>-.9177109***</td>
</tr>
<tr>
<td>Zgc</td>
<td>-.149658***</td>
</tr>
</tbody>
</table>
### Rules of the same planner, by questionnaire

<table>
<thead>
<tr>
<th>Category</th>
<th>PIF</th>
<th>Weight</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td></td>
<td>R</td>
</tr>
<tr>
<td>1. Basic topography</td>
<td>1. Elevation</td>
<td>0.32</td>
</tr>
<tr>
<td></td>
<td>2. Slope</td>
<td>0.30</td>
</tr>
<tr>
<td>2. Accessibilities</td>
<td>2.1 Transport facilities</td>
<td>3. Airports</td>
</tr>
<tr>
<td></td>
<td>4. Rail stations</td>
<td>0.26</td>
</tr>
<tr>
<td></td>
<td>5. Highways</td>
<td>0.23</td>
</tr>
<tr>
<td></td>
<td>6. Main roads</td>
<td>0.30</td>
</tr>
<tr>
<td></td>
<td>7. Subway stations</td>
<td>0.43</td>
</tr>
<tr>
<td></td>
<td>8. Bus stops</td>
<td>0.42</td>
</tr>
<tr>
<td>2.2 Public facilities</td>
<td>9. Government departments</td>
<td>0.39</td>
</tr>
<tr>
<td></td>
<td>10. Entertainment facilities</td>
<td>0.49</td>
</tr>
<tr>
<td></td>
<td>11. Amenities (such as supermarkets)</td>
<td>0.50</td>
</tr>
<tr>
<td></td>
<td>12. Medical and health institutions</td>
<td>0.57</td>
</tr>
<tr>
<td></td>
<td>13. Educational and research institutions</td>
<td>0.58</td>
</tr>
<tr>
<td></td>
<td>14. Banks and insurers</td>
<td>0.36</td>
</tr>
<tr>
<td></td>
<td>15. Parks and attractions</td>
<td>0.55</td>
</tr>
<tr>
<td>2.3 Location</td>
<td>16. CBD</td>
<td>0.33</td>
</tr>
<tr>
<td>4. Socioeconomic characteristics</td>
<td>22. Land price</td>
<td>0.33</td>
</tr>
<tr>
<td></td>
<td>23. Population density</td>
<td>0.36</td>
</tr>
<tr>
<td></td>
<td>24. Employment rate</td>
<td>0.30</td>
</tr>
<tr>
<td>5. Environment</td>
<td>25. Air quality</td>
<td>0.46</td>
</tr>
<tr>
<td></td>
<td>26. Traffic noise</td>
<td>0.56</td>
</tr>
<tr>
<td></td>
<td>27. Vegetation coverage</td>
<td>0.49</td>
</tr>
<tr>
<td></td>
<td>28. NIMBY facilities</td>
<td>0.46</td>
</tr>
</tbody>
</table>

Total 20 planners surveyed in BICP (planners) and PKU (plan students)
Comparison to be conducted
Comparison of mined and surveyed rules

What has done and will do are generally different, in terms of taste of each land use on various factors.
Three scenarios by different planners

<table>
<thead>
<tr>
<th>Land use type</th>
<th>Parcel number (scenario A)</th>
<th>Parcel number (scenario B)</th>
<th>Parcel number (scenario C)</th>
</tr>
</thead>
<tbody>
<tr>
<td>R</td>
<td>163</td>
<td>157</td>
<td>130</td>
</tr>
<tr>
<td>C</td>
<td>116</td>
<td>146</td>
<td>182</td>
</tr>
<tr>
<td>M</td>
<td>11</td>
<td>7</td>
<td>8</td>
</tr>
<tr>
<td>O</td>
<td>46</td>
<td>26</td>
<td>16</td>
</tr>
<tr>
<td>Total</td>
<td>336</td>
<td>336</td>
<td>336</td>
</tr>
</tbody>
</table>
Evaluating scenarios

• A framework for energy consumption and carbon emission based on planned land use patterns
  – 1.1 Population synthesis for generating resident and business agents (finished in BUDEM2)
  – 1.2 Building reconstruction for planned parcels (in progress)
  – 2 Activity- and agent-based impact simulation (challenging)
  – 3 Impact accounting

• Commuting section finished

• A low carbon scenario is possible to be identified
Ideas could be borrowed from other talks, e.g.

• **Yang Jiang**
  – Proposal of a Modeling Approach to Assess Urban Energy Consumption and Carbon Emissions based on Spatial Structure and Form

• **Tony Hargreaves**
  – Estimating the building stock from regional model forecasts and its low carbon potential

• **ZHANG Jie, XIE Yang**
  – Urban spatial morphology's impact on household transportation energy consumption

• **Feifei Yu, Chris Zegras**
  – An integrated behavioral model for estimating energy consumption at the neighborhood scale
4 CONCLUSIONS
Conclusions

• Planner Agents for supporting land use pattern scenario analysis (LUPSA)
  – Limited to land use plan in the master plan level
  – A tool
  – Identified rules by questionnaire and data mining
  – A very preliminary research in its first step
• Tested in the hypothetical space and applied in Beijing
  – Compile and evaluate land use plan quantitatively
• Promising in promoting working efficiency of planners
  – Jobless planners?
  – Expected to support planning low carbon a urban form
Next steps

• Polish existing work
• Evaluate simulated patterns
• Rules for density distribution
Limited spatial plan implementation effectiveness in China (around 50% outside planned urban growth boundaries).

See Han et al, 2009; Long et al, 2012; Tian and Shen, 2011

The value for promoting urban plan compilation efficiency?

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THANKS FOR YOUR ATTENTION!