Adaptive Planning Policy and Practice. The opportunities provided by Big data and dynamic simulation models in an era of digital cities

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OUTLINE

1. The argument in favor of adaptive policy and need for ‘Big/live Data’

2. Complexity theory: The right moment in time to link planning decision and urban models
   -Matching the key attributes of PPS -DSS with Dynamic Simulation and Planning Decisions (Policy Support) & some level of ‘Soft’ AI

3. Key areas to address: Metrics, Methods, Calibration, Validation, Randomness, uncertainty, data-mining

4. The examples of models: The SLEUTH model; The CVCA model; CCID model; IUBEA, The DG-ABC model, climate change negotiation and COP (more than big trends are the selection of packages, adaptation in time/space and 10% efficiency gain)
1. The argument in favor of adaptive policy for spatial planning
Cities and landscapes evolve - in time and space (across scales and along the same scale)

The rational models of the 50-70s - systems theory or participative theory they are both based on the ‘presumption of certainty’ - they provide one answer to the decision maker (static snapshot of time – a map, a result)

Historical evolution is due to theory, practice, professional qualifications/numbers, computation, data constraints
The simplified reality of static world resulting from overlays of data is not enough.

‘Today’ is a result of complex physical and social interactions that have in account past events and future expectations.

Pure causation is not enough and cumulative effects, ‘carrying capacity’, self-organization, etc. play important roles.

Complexity theory
2. Complexity theory: The right moment in time to link planning decision and urban models

- Mismatch between technology, theory, data of the 70s resulted in Lees' "Requiem for large scale models"

- XXI century of Big Data, high computation capability, vast numbers of experts, more data-aware policy, metrics, calibration, validation, randomness

Starting the study of complex systems in Spatial Analysis ...

- Waldo Tobler in contact with Arthur Burks was exposed to Von Neumann’s works, and published ‘Cellular Geography’ (1979).

- At NCGIA-Santa Barbara, Helen Couclelis and Keith Clarke, published respectively ’Cellular Worlds’ (Couclelis, 1985) and develop the first fully operational and implementable CA (Clarke and Gaydos, 1998). While et. since the 1990’s focus in the ‘adaptive’ CA as a basis basis of integrated dynamic regional analysis (1997)

- Michael Batty initially at NCGIA-Buffalo and afterwards at CASA-UCL, developed the theory and practice that culminated in the publication of the seminal books ’Fractal Cities’ (1994) and ‘Cities and complexity’ (2005). Recently, Wolfram’s book ‘A New Kind of Science’ (2002)

- ES = 3rd Generation (consolidation, reassemble, expansion, randomness, validation)
Complexity Theory

Data science

Feedback loops of learn/adapt/enrich knowledge

System theory

Advocacy of Planning

Beyond modernity

Participative Planning

Rational Planning

Incremental Planning

Mix-Scanning (Zoom in-out, Top/down-b/up)

Deterministic

Stochastic

Theory

Processes

Models

focus

Physical regions

People/social

focus

Processes

Models

Time

Deterministic

Stochastic

50s
Operational Dynamic Urban Models
1. SLEUTH
### Transition Rules:

<table>
<thead>
<tr>
<th>Rule</th>
<th>Probability</th>
<th>Action Step</th>
</tr>
</thead>
<tbody>
<tr>
<td>1. Protective</td>
<td>0 but NN &gt; MNND</td>
<td>than add protective pixels around all outer patch and add protective pixels until arriving at closest neighbor</td>
</tr>
<tr>
<td>2. Defensive</td>
<td>&lt;=50% *, **</td>
<td>than add defensive pixels to all outer patch cell where transition cell exists</td>
</tr>
<tr>
<td>3. Offensive</td>
<td>&gt;50%</td>
<td>add offensive pixel to all outer patch cells and add offensive cells until nearest neighbor</td>
</tr>
<tr>
<td>4. Opportunistic</td>
<td>0 but NN = NNI</td>
<td>(and no transition cell nearby) than link to nearest neighbor</td>
</tr>
<tr>
<td>5. Grow</td>
<td></td>
<td></td>
</tr>
</tbody>
</table>

### Action Steps:

**A. Protective**
- Desired network elements are identified and protected through planning policy and land use control in advance of negative landscape matrix changes.

**B. Defensive**
- Isolated core area in ‘non-supportive landscape matrix’ is subject to isolation from disturbance to corridors and to incremental reduction in size of the core area that can be protected through a new buffer zone.

**C. Offensive**
- Isolated core area is protected with a buffer zone and linked into a greenway network with corridors that are newly developed within a non-supportive landscape matrix context. The offensive strategy employs a range of tactics, including nature development, to achieve a desired landscape configuration.

**D. Opportunistic**
- Isolated core area is linked with an existing corridor, buffered, and anew supporting landscape matrix is developed. The opportunistic strategy takes advantage of unique circumstances that may only support some greenway uses, e.g. recreation.

### Existing Landscape

- **Core**
- **Supporting Landscape**
- **Buffer Zone**
- **Non-Supporting Landscape Matrix**
- **Corridor**

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ADVANCED SPATIAL MODELING AND ANALYSIS, 2nd Conf., CEG-IGOT
7.7.2016

[Logo: University of Cambridge]
TWO MAP DRAWINGS RESULTING FROM THE WORKSHOP’S AFTERNOON
## SWOT RESULTS

<table>
<thead>
<tr>
<th>Strengths</th>
<th>Votes</th>
<th>Weakness</th>
<th>votes</th>
<th>Opportunities</th>
<th>Votes</th>
<th>Threats</th>
<th>votes</th>
</tr>
</thead>
<tbody>
<tr>
<td>Transport system (road network, airport, harbor)</td>
<td>19.5</td>
<td>Mobility, accessibility and transport</td>
<td>32.6</td>
<td>Improve transportation system</td>
<td>17.6</td>
<td>Uncontrolled urban sprawl</td>
<td>29.9</td>
</tr>
<tr>
<td>Tourism and world heritage (Lisbon and Porto)</td>
<td>17.8</td>
<td>Lack of urban quality</td>
<td>17.0</td>
<td>Urban renewal</td>
<td>15.7</td>
<td>Natural risks (e.g. coastal, flooding, earthquake)</td>
<td>16.4</td>
</tr>
<tr>
<td>Capital city</td>
<td>13.0</td>
<td>Uncontrolled urban sprawl</td>
<td>11.3</td>
<td>Cultural tourism/events</td>
<td>11.8</td>
<td>Urban violence and drugs</td>
<td>14.2</td>
</tr>
</tbody>
</table>
- The image of a city-region
- Identification/quantification
- Urban forms (existent /possible)

- “same future” – different simulations

Data: satellite images and other LU-LCover (year-by-year)
**Research Objectives**

- To track energy change
  - Energy change of London
  - Energy change per local authority / buildings
- To estimate and analyze Energy Usage Intensities (EUI)
  - EUI of Local Authorities
  - EUI of sub-categories of buildings
- To explain energy consumption
  - Explain how the distribution of land use influences energy consumption in local authorities and the entire city of London
  - Explain how the distribution of floor area influences energy consumption
- To evaluate energy performance
  - Evaluate energy performance of London while adapting different energy change policies.
  - Interactive Simulation Model for predicting energy performance in the future on the basis of population change.
- **Baseline scenario**
  - The baseline scenario is based on prior knowledge on energy use intensity in terms of building types.
  - Three methods are provided:
    - benchmark values
    - median values
    - Monte Carlo method
  - Analysts may choose one or all these three methods based on data availability.

- **(1) Electrification**
  - This scenario is to explore how the total energy or carbon emissions would change if building sector would use electricity instead of gas for heating.

- **(2) Building type conversion**
  - This Scenario investigates the change of building types on the energy consumption in cities.

- **(3) Energy efficient**
  - This scenario allows analysts studying the influences of change of energy use intensities for different building types.
  - Note: The benchmark values are based on low, typical, and high values (EUI) from previous literature.

- **Energy scenario analysis (what-if analysis)**
  - This method is more flexible compared to regression analysis because it is suitable for the situation where energy consumption data are unavailable in some spatial scales or some areas of a city.
To compute the overall difference of floor area percentage to best-performing area in terms of gas use intensity at London MSOA level.

The overall differences of floor area percentage based on gas use intensity still present the characteristics of spatial distribution to some extent, though not clustered as large area.

Spatial distribution demonstrates that energy consumptions in an area are to some extent influenced by where the area is located in a city.

**Result:** Energy optimization based on building types at MSOA level in London
Liu, Wang and Silva -- CI Agent Base Model

- **Model Structure**
  - **New Policies for Cls, CWs and New Land-use Plan**
    - Influence upon land-use type and citizens of neighbouring plots
    - New policies for CIs, CWs and new land-use plan

- **Spatial Structure of CIs Firms**
  - Determinants for CIs firms' location choosing
  - Variation in CIs firms' number & size

- **Spatial Structure of CWs' Habitation**
  - Demand for housing
  - Variation in CWs population

- **Demand for CIs Firms**
  - Land expropriation, urban regeneration
  - New housing estate
  - Compensation

- **Development of CIs**
  - New housing estate
  - Compensation
  - To accept
  - To refuse

- **Demand for Office**
  - Interchange & feedback
  - Demand for housing
  - Existing housing estate

- **Urban Government**
  - Demand for office
  - To refuse

- **Individual Citizens**
  - Compensation
  - To accept
  - To refuse

- **New Policies for CWs, CIs and New Land-use Plan**
  - Interaction & feedback
  - New policies for CWs, CIs, and new land-use plan

- **Determinants for CWs' Location Choosing**
  - Demand for housing
  - Variation in CWs population

- **Expectation & Feedback**
  - Supply
  - Expectation & feedback

- **Advocating, Regulating & Controlling**
  - To refuse
  - To accept
Data: economic statistic data +300 firms and +2000 (+++questionnaires and semi-structured interviews) (month-by-month)

Agents and terms for negotiation
Crawford-Brown, Liu, Silva

• Agents: 196 countries
  – Annex1 (42)
  – No Annex1 (149)
  – Others (5)

• Terms for negotiation
  – Technology trade
  – Carbon trade
  – GDP growth support

• Negotiation rules

Table 1 The three adoptable strategies and their influence on the two involved countries

<table>
<thead>
<tr>
<th>country</th>
<th>Carbon Sells</th>
<th>Technology Sells</th>
<th>GDP growth support</th>
</tr>
</thead>
<tbody>
<tr>
<td>A as sender</td>
<td>Technology (Carbon/GDP)</td>
<td>↑</td>
<td>--</td>
</tr>
<tr>
<td>Extra Carbon emission</td>
<td>--</td>
<td>--</td>
<td>↓</td>
</tr>
<tr>
<td>GDP growth rate</td>
<td>--</td>
<td>↑</td>
<td>--</td>
</tr>
<tr>
<td>B as receiver</td>
<td>Technology (Carbon/GDP)</td>
<td>--</td>
<td>↑</td>
</tr>
<tr>
<td>Extra Carbon emission</td>
<td>↑</td>
<td>--</td>
<td>↑</td>
</tr>
<tr>
<td>GDP growth rate</td>
<td>↑</td>
<td>↓</td>
<td>↑</td>
</tr>
</tbody>
</table>
Data: minutes of meetings + socio-economic data + agreements data (year-by-year)
### Three scenarios

<table>
<thead>
<tr>
<th>Parameter's name</th>
<th>Connection to the dynamics</th>
<th>scenario A: Low Ambition</th>
<th>scenario B: Medium Ambition</th>
<th>Scenario C: High Ambition</th>
</tr>
</thead>
<tbody>
<tr>
<td>gdp-per-capita-emission-concerned (USD/Capita*Year)</td>
<td>A global variable for recording the critical value for GDP/capita. Countries with GDP/capita lower than this value will not join in the bilateral negotiation.</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>carbon-per-capita-critical value (t CO₂/Capita*Year)</td>
<td>A global variable for recording the critical value for carbon emission / capita. Only countries with carbon emission/capita lower than this value can be free from the responsibility to reduce carbon emission.</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>critical-carbon-emission-per-gdp (t CO₂/USD)</td>
<td>A global variable for recording the critical value for carbon emission / GDP. Each country involved in the negotiation process is responsible to reduce its carbon emission intensity to a level lower than this value.</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>critical-minimum-co2pergdp (t CO₂/USD)</td>
<td>A global variable to describe the ultimate ability of our society to reduce carbon emission / GDP.</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>mean-agreement-duration (Years)</td>
<td>A global variable to describe the average duration of the agreements signed between two countries. The duration of each signed agreement may be different but their mean duration is constrained to this critical value.</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>gdp-growth-rate-decrease-rate-critical (%/Year)</td>
<td>A global variable for recording the acceptable decrease rate of GDP growth rate for all the countries due to signed agreements. A country will not sign too many agreements which may reduce its GDP growth rate by more than this critical value.</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>carbon-emission-increase-rate-critical (%/Year)</td>
<td>A global variable for recording the acceptable increase rate of carbon emission for all the countries due to signed agreements. A country will not sign too many agreements which may increase its GDP growth rate by more than this critical value.</td>
<td></td>
<td></td>
<td></td>
</tr>
</tbody>
</table>
MT masts

Data: 70% of all geo-data telecommunications traffic
(minute-by-minute)
Data structure – adding to the mobile google feeds

### Table 4: Temporal Resolution

<table>
<thead>
<tr>
<th>Temporal</th>
<th>Index</th>
</tr>
</thead>
<tbody>
<tr>
<td>Daily</td>
<td>0630</td>
</tr>
<tr>
<td></td>
<td>0800</td>
</tr>
<tr>
<td></td>
<td>1100</td>
</tr>
<tr>
<td></td>
<td>1300</td>
</tr>
<tr>
<td></td>
<td>1500</td>
</tr>
<tr>
<td></td>
<td>1730</td>
</tr>
<tr>
<td></td>
<td>1900</td>
</tr>
<tr>
<td>Weekly</td>
<td>Mon/Tue</td>
</tr>
<tr>
<td></td>
<td>Wed/Thur</td>
</tr>
<tr>
<td></td>
<td>Friday</td>
</tr>
<tr>
<td></td>
<td>Saturday</td>
</tr>
<tr>
<td></td>
<td>Sunday</td>
</tr>
<tr>
<td>Monthly</td>
<td>Jan/Feb</td>
</tr>
<tr>
<td></td>
<td>Mar/Apr</td>
</tr>
<tr>
<td></td>
<td>May/Jun</td>
</tr>
<tr>
<td></td>
<td>Jul/Aug</td>
</tr>
<tr>
<td></td>
<td>Sep/Oct</td>
</tr>
<tr>
<td></td>
<td>Nov/Dec</td>
</tr>
</tbody>
</table>

### Table 5: Simplified illustration of Journey_table data

<table>
<thead>
<tr>
<th>Journey_ID</th>
<th>Time_stamp</th>
<th>Distance</th>
<th>Duration</th>
<th>Origin_ID</th>
<th>Destination</th>
</tr>
</thead>
<tbody>
<tr>
<td>5</td>
<td>1425207218</td>
<td>3697</td>
<td>502</td>
<td>3456</td>
<td>1</td>
</tr>
<tr>
<td>6</td>
<td>1425207218</td>
<td>3174</td>
<td>529</td>
<td>1732</td>
<td>2</td>
</tr>
<tr>
<td>7</td>
<td>1425207219</td>
<td>5073</td>
<td>723</td>
<td>252</td>
<td>3</td>
</tr>
</tbody>
</table>
Planning & Transport - Operational Dynamic Urban Models

Agent based transport modelling with real-time big-data

**Main goal:** Life cycle transport carbon comparisons

**Key innovations:**
- Dynamic model
- Real-time crowd-sourced inputs
- Scenario testing (what if?)

Traffic
Distribution
Global Map
Time
Scenario Testing – what if?

1. What if we close Westminster Bridge?
2. This agent’s new route

Example what if questions:
1. New railways lines
2. Autonomous vehicles
3. Smarter data for travelers
4. New congestion charges
5. Emission taxes

London, UK-

By: Casey, Soga, Guthrie, Silva, Zhao, Kumar, Bak

Data: Google feeds (geo-positioning data) + other data (Dft) (minute-by-minute+hour-by-hour)
Planning & Transport - Operational Dynamic Urban Models

Network level transport infrastructure degradation simulation and maintenance planning

ALL-IN-ONE degradation model for roads, railways and undergrounds;

BOTTOM-UP simulation of infrastructure condition change, retaining information for as small as meter-level sections;

CITY-SCALE modelling empowered by advanced spatial dynamic simulation techniques, allowing fast scenario testing of maintenance strategies.

London, UK-

By: Zhao, Soga, Silva

Data: 1:500 – 1:50000

Hour-by-hour/day-by-day

Mapping the existing information

- Transport network, climate and environment, infrastructure condition, usage and maintenance records
- Significant factors affecting the degradation of transport infrastructures

Simulating infrastructure conditions using Cellular Automata

- Knowledge of the degradation behaviours of transport infrastructures
- Computational intensive calibration for the specific study area/case
- A network level model for predicting infrastructure conditions in the study area

Addressing challenges and constrains

- New trends in urban transportation and asset management: smart sensors, early detection of defects...
- Maintenance backlog, limited budget, regional competition for funding allocation, ...
- Scenario testing and decision making support
## A. Global variables

<table>
<thead>
<tr>
<th>Name</th>
<th>Description</th>
</tr>
</thead>
<tbody>
<tr>
<td>vboundary</td>
<td>Vector data layer of Greater London boundary</td>
</tr>
<tr>
<td>vrail</td>
<td>Vector data layer of railway network</td>
</tr>
<tr>
<td>vgeology</td>
<td>Vector data layer of superficial geology</td>
</tr>
<tr>
<td>rtemperature</td>
<td>Raster data layer of temperature</td>
</tr>
<tr>
<td>wrail_geology</td>
<td>Exponent weight assigned to the geology factor during railway degradation</td>
</tr>
<tr>
<td>wrail_temperature</td>
<td>Exponent weight assigned to temperature during railway degradation</td>
</tr>
<tr>
<td>orial_con</td>
<td>Overall condition of the railway network, calculated as the percentage of rail sections in “good” condition band</td>
</tr>
<tr>
<td>difference</td>
<td>Difference between simulated conditions and observations, calculated as the percentage of railway sections whose simulated condition do not match the observed condition.</td>
</tr>
</tbody>
</table>

![Figure 4.7 Simulation outcomes at time step 1, 2 and 3 based on different combinations of weighing](image-url)
Example

- Smart routing
  - Traffic on already degraded roads/railways is not desirable:
    - Less comfortable
    - More damage to the vehicle
    - More detrimental to degradation
    - Higher environmental impacts
  - Shall we guide the traffic to use better conditioned routes?
Planning & Transport -

Operational Dynamic Urban Models – Activity Base

“Can we reduce the number of unnecessary movements in a city?”, “can we opti. location of infrastructures?”

- Beijing 24 h travel
- Travel diary data containing ca 60,000 individuals and 200,000 trips
- Travel attitude and household week travel survey on 200 samples

- Linkage between TAZs on weekdays
- Linkage between TAZs on weekends

Beijing, China - By: L. Liu, Silva
Planning & Transport - Operational Dynamic Urban Models

Land Use & Activity Based Planning

“Can we reduce the number of unnecessary movements in a city?”, “can we optimize location of infrastructures?”

Case Study: Kumasi Metropolis, Ghana West Africa

Data: O/D surveys /questionnaires + LU + activity /socio-economic data/month -by-month

Accra City Region and Kumasi Metropolics

By: Acheampong, Agyemang, Silva
Some Papers


2012 Surveying Models in Urban Land Studies. (with N. Wu) Journal of Planning Literature. 27 (): 1-14


2004 The DNA of our Regions: artificial intelligence in regional planning. Futures, 36(10):1077-1094. – ISSN: 0016-3287

Some book chapters


Elisabete (es424@cam.ac.uk)
www.landecon.cam.ac.uk/directory/esilva

LISA Lab
www.landecon.cam.ac.uk/research/lisa

Forthcoming Book: "Comprehensive Geographic Information Systems “ (vol.3), Elsevier

Books: