Maintain, Demolish, Re-purpose: Policy Design for Vacant Land Management using Decision Models

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Policy motivation

- Neighborhoods, cities, regions and countries face sustained economic and population decline, due to lower population growth rates, deindustrialization and sustained disinvestment, and the housing foreclosure crisis.

- Planners increasingly see ‘decline’ as something to plan for: a place may lose population while ensuring a high quality of life and enhanced social value (Delken 2008, Hollander 2010).

- Growth-oriented planning continues to maintain its hegemony over local government decision-making.

Can decision models help planners devise strategies that will maximize the social value of managed decline?
What is shrinkage?

- Smart decline: ‘planning for less, fewer people, fewer buildings, fewer land uses’ (Popper and Popper 2002)
- Reduction in level of public services (Popper and Popper 2002):
  - Fixed assets: closure/consolidation/re-purposing of schools, fire stations, libraries
  - Services: reduced maintenance of infrastructure, outsourcing, furloughs/layoffs
- Transformative investments (Hollander 2010):
  - Subdivision of owner-occupied single family homes into multi-family rentals
  - Demolition of homes
  - Conversion of vacant lots to urban agriculture, parks and community gardens and environmental remediation
What cities and regions face shrinkage?

- Flint, Michigan (Hollander 2010)
- Youngstown, Ohio (Hollander 2009)
- Buffalo, New York (Hollander and Cahill 2011)
- Great Plains region of the Midwest (Popper and Popper 2004)
- Leipzig, Germany (Banzhaf, Kindler and Haase 2007)
- Southwest US and central Florida (Hollander 2012)
What is new about shrinkage?

- Permanence of new economic and social constraints
- Acceptance of need for new land uses
- Managed decline is one of multiple planning/policy strategies for a region, or portions of a region
Key modeling concepts

- **Neighborhood-level investments**
  - Residential-focused investments maintain or enhance existing residential and commercial uses
  - Non-residential-focused investments enable residential and commercial uses to be converted to a variety of passive or recreational uses

- **Growth policies**
  - Smart growth attempts to maintain or increase residential population in a sustainable manner
  - Smart decline seeks to reduce residential population and while preserving overall quality of life
Research questions

- What levels of residential- and non-residential-focused investments in each neighborhood within our study area jointly optimize multiple social objectives?
- What model formulations are associated with smart growth, smart decline or ‘no action’ policies within and across neighborhoods?
Modeling preliminaries

Assumptions

- Different neighborhoods respond differently to residential-focused versus non-residential-focused investments.
- Perceived equity (fairness) can determine political feasibility of planning strategies.
- Neighborhood-level investments may result in economies or diseconomies of scale over space.

Challenges

- Planners may view concerns with equity and neighborhood-level engagement design as incompatible with regional-level and quantitatively-focused decision modeling.
- OR/MS can be seen as confirming (or not questioning) traditional power relationships or notions of knowledge.
Municipal shrinkage planning problem

- **Goal:** Choose investment levels across neighborhoods that support residential and/or non-residential uses

- **Objectives:**
  - Maximize neighborhood satisfaction associated with residential and non-residential investments
  - Maximize clustering of neighborhood investments, to capture economies of scale
  - Maximize the perceived equity, or fairness of a city-wide development plan

- **Constraints:**
  - Limit levels of residential and non-residential investments within and across neighborhoods
How can we model neighborhood satisfaction?

- **Research evidence:**
  - Negative social impacts of proximity to vacant land (Branas et al., 2011)
  - Resident opinions on neighborhood quality are heterogeneous and not synonymous with growing cities (Hollander 2011)

- **Assumptions:**
  - Neighborhood satisfaction is
    - Salient to residents and non-residents
    - Associated with quality of life and level of neighborhood investments
    - Derived from residential-focused and non-residential-focused investments
  - Neighborhoods respond differently to investments:
    - A *high-impact* neighborhood shows increasing returns to scale
    - A *low-impact* neighborhood shows decreasing returns to scale
    - A *moderate-impact* neighborhood shows constant returns to scale
Neighborhood satisfaction functions

- Model parameters:
  - $A_i$ = index of neighborhood attractiveness
  - $r_i$ = level of residential-focused investment
  - $n_i$ = level of non-residential-focused investment
  - $x$ = scale factor for residential-focused investments
  - $y$ = scale factor for non-residential-focused investments

- Residential-oriented neighborhood satisfaction function:
  \[ S^r_i = f_i(r_i; A_i) \equiv A_i \cdot r_i^x \]

- Non-residential-oriented neighborhood satisfaction function:
  \[ S^n_i = g_i(n_i, A_i) \equiv \frac{1}{A_i} \cdot n_i^y \]

where:
- $x$ ($y$) = 1 for moderate impact neighborhoods
- $x$ ($y$) > 1 for high impact neighborhoods
- $x$ ($y$) < 1 for low impact neighborhoods
Complete model

Objectives:
Max

\[
S(r, n) = \left( \frac{1}{A_i} \right) \cdot r_i^x + A_i \cdot n_i^y
\]

\[
C(y) = \sum_{i=1}^{I} \sum_{j=1}^{J} y_{i,j}
\]

\[
E_1(r) = \min_{i=1,2,...,I} \left\{ \frac{r_i}{B_i^r} \right\}
\]

\[
E_2(n) = \min_{i=1,2,...,I} \left\{ \frac{n_i}{B_i^n} \right\}
\]

Constraints:

\[
r_i \leq B_i^r \quad \forall i
\]

\[
n_i \leq B_i^n \quad \forall i
\]

\[
\sum_{i=1}^{I} r_i \leq B^r
\]

\[
\sum_{i=1}^{I} n_i \leq B^n
\]

\[
\max(B^r, B^n) \leq \sum_{i=1}^{I} (r_i + n_i) \leq B^r + B^n
\]

\[
y_{ij} \leq \frac{r_i + n_i}{d_{ij}} \quad \forall i, j
\]
MSPP description and solution approach

- Non-linear multi-objective math optimization problem
- Generate approximation to Pareto frontier
  - Initially: weighting method (Cohon 1978)
  - Generally: contemporary methods (Collette and Siarry 2002; Ehrgott 2005; Ehrgott and Gandibleux 2002; Miettinen 1999)
- Classify neighborhood investment strategy \( \{r_i^*, n_i^* \} \) as:
  - Smart growth policy if \( r_i^* > n_i^* \),
  - Smart decline policy if \( n_i^* > r_i^* \),
  - No-action policy otherwise
- Similar definitions apply for study area
Case study

- Goal: apply municipal shrinkage planning problem to real city

- Candidates:
  - MA ‘gateway cities’
  - ‘Great’ cities
  - Cities traditionally focus of smart decline scholarship

- Method:
  - Identify metrics of distress/decline (cf Wolff 2009)
  - Select candidates with greatest number of distress measures
## MA gateway cities

<table>
<thead>
<tr>
<th>City</th>
<th>% Change in population 1990-2000</th>
<th>% Change in population 2000-2010</th>
<th>Change in housing vacancy rate 2000 - 2010</th>
<th>Change in poverty rate 2000 - 2010</th>
<th>% Change in civilian employed 2000 - 2010</th>
<th>Change in unemployment rate 2000 - 2010</th>
<th>Distress in how many categories?</th>
</tr>
</thead>
<tbody>
<tr>
<td>Brockton</td>
<td>1.61%</td>
<td>-0.52%</td>
<td>4.8</td>
<td>0.7</td>
<td>0.3</td>
<td>5.4</td>
<td>2</td>
</tr>
<tr>
<td>Fall River</td>
<td>-0.83%</td>
<td>-3.35%</td>
<td>6.1</td>
<td>4.6</td>
<td>-3.1</td>
<td>5</td>
<td>5</td>
</tr>
<tr>
<td>Fitchburg</td>
<td>-5.35%</td>
<td>3.11%</td>
<td>8.9</td>
<td>2.9</td>
<td>0.9</td>
<td>1.5</td>
<td>1</td>
</tr>
<tr>
<td>Haverhill</td>
<td>12.81%</td>
<td>3.24%</td>
<td>4.1</td>
<td>1.4</td>
<td>-0.9</td>
<td>3.7</td>
<td>0</td>
</tr>
<tr>
<td>Holyoke</td>
<td>-9.70%</td>
<td>0.11%</td>
<td>-2.5</td>
<td>3.6</td>
<td>-2.5</td>
<td>3</td>
<td>3</td>
</tr>
<tr>
<td>Lawrence</td>
<td>2.55%</td>
<td>6.02%</td>
<td>3</td>
<td>3.4</td>
<td>5</td>
<td>-0.2</td>
<td>1</td>
</tr>
<tr>
<td>Lowell</td>
<td>1.64%</td>
<td>1.29%</td>
<td>6.2</td>
<td>0.9</td>
<td>0.4</td>
<td>1.7</td>
<td>1</td>
</tr>
<tr>
<td>New Bedford</td>
<td>-6.56%</td>
<td>1.39%</td>
<td>3.1</td>
<td>2.5</td>
<td>2.7</td>
<td>1.8</td>
<td>1</td>
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<tr>
<td>Pittsfield</td>
<td>-6.18%</td>
<td>-2.31%</td>
<td>0.5</td>
<td>2.8</td>
<td>0.1</td>
<td>2.5</td>
<td>2</td>
</tr>
<tr>
<td>Springfield</td>
<td>-3.22%</td>
<td>0.64%</td>
<td>4.7</td>
<td>2.7</td>
<td>-4.3</td>
<td>4.1</td>
<td>2</td>
</tr>
<tr>
<td>Worcester</td>
<td>1.67%</td>
<td>4.86%</td>
<td>5.9</td>
<td>0.2</td>
<td>0</td>
<td>2.9</td>
<td>0</td>
</tr>
</tbody>
</table>
## Selected large cities

<table>
<thead>
<tr>
<th>City</th>
<th>% Change in population 1990-2000</th>
<th>% Change in population 2000-2010</th>
<th>Change in housing vacancy rate 2000 - 2010</th>
<th>Change in poverty rate 2000 - 2010</th>
<th>% Change in civilian employed 2000 - 2010</th>
<th>Change in unemployment rate 2000 - 2010</th>
<th>Distress in how many categories?</th>
</tr>
</thead>
<tbody>
<tr>
<td>Baltimore</td>
<td>-13.03%</td>
<td>-4.64%</td>
<td>5.7</td>
<td>1.2</td>
<td>2</td>
<td>2.8</td>
<td>2</td>
</tr>
<tr>
<td>Boston</td>
<td>2.52%</td>
<td>4.83%</td>
<td>4.5</td>
<td>2.3</td>
<td>1.1</td>
<td>4.2</td>
<td>1</td>
</tr>
<tr>
<td>Detroit</td>
<td>-8.06%</td>
<td>-24.97%</td>
<td>18.9</td>
<td>10.6</td>
<td>-11.6</td>
<td>10</td>
<td>6</td>
</tr>
<tr>
<td>Las Vegas</td>
<td>46.01%</td>
<td>22.01%</td>
<td>9.6</td>
<td>3.4</td>
<td>-3.2</td>
<td>5.2</td>
<td>2</td>
</tr>
<tr>
<td>Albuquerque</td>
<td>14.24%</td>
<td>21.68%</td>
<td>-0.7</td>
<td>4.6</td>
<td>-1.2</td>
<td>1.5</td>
<td>0</td>
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<tr>
<td>New York City</td>
<td>8.56%</td>
<td>2.08%</td>
<td>4.2</td>
<td>-1.5</td>
<td>3.6</td>
<td>1.5</td>
<td>1</td>
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<tr>
<td>Charlotte</td>
<td>26.79%</td>
<td>35.24%</td>
<td>4.8</td>
<td>5.9</td>
<td>-5.8</td>
<td>5.5</td>
<td>3</td>
</tr>
<tr>
<td>Columbus</td>
<td>11.04%</td>
<td>10.62%</td>
<td>6</td>
<td>7.3</td>
<td>-4.8</td>
<td>5.3</td>
<td>3</td>
</tr>
<tr>
<td>Oklahoma City</td>
<td>12.13%</td>
<td>14.59%</td>
<td>2.5</td>
<td>1.1</td>
<td>1.5</td>
<td>2</td>
<td>0</td>
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<tr>
<td>Portland</td>
<td>17.35%</td>
<td>10.33%</td>
<td>1.8</td>
<td>4.9</td>
<td>-4</td>
<td>3.9</td>
<td>1</td>
</tr>
<tr>
<td>Philadelphia</td>
<td>-4.48%</td>
<td>0.56%</td>
<td>3.2</td>
<td>2.9</td>
<td>-1.1</td>
<td>3</td>
<td>2</td>
</tr>
</tbody>
</table>
## Selected ‘shrinkage’ cities

<table>
<thead>
<tr>
<th>City</th>
<th>% Change in population 1990-2000</th>
<th>% Change in population 2000-2010</th>
<th>Change in housing vacancy rate 2000 - 2010</th>
<th>Change in poverty rate 2000 - 2010</th>
<th>% Change in civilian employed 2000 - 2010</th>
<th>Change in unemployment rate 2000 - 2010</th>
<th>Distress in how many categories?</th>
</tr>
</thead>
<tbody>
<tr>
<td>Flint, MI</td>
<td>-12.66%</td>
<td>-18.02%</td>
<td>11</td>
<td>10.9</td>
<td>-13.5</td>
<td>5.2</td>
<td>6</td>
</tr>
<tr>
<td>Ashland, KY</td>
<td>-7.47%</td>
<td>-1.35%</td>
<td>1.1</td>
<td>2.4</td>
<td>-0.9</td>
<td>1.4</td>
<td>0</td>
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<tr>
<td>Youngstown, OH</td>
<td>-16.71%</td>
<td>-18.34%</td>
<td>5.8</td>
<td>7.3</td>
<td>-3.3</td>
<td>4.5</td>
<td>4</td>
</tr>
<tr>
<td>New Orleans, LA</td>
<td>-2.53%</td>
<td>-29.06%</td>
<td>11.6</td>
<td>-3.1</td>
<td>3.9</td>
<td>2.2</td>
<td>2</td>
</tr>
<tr>
<td>Cleveland, OH</td>
<td>-5.69%</td>
<td>-17.05%</td>
<td>10.1</td>
<td>5.6</td>
<td>-2.6</td>
<td>5.2</td>
<td>3</td>
</tr>
<tr>
<td>Buffalo, NY</td>
<td>-12.12%</td>
<td>-10.71%</td>
<td>2.2</td>
<td>3.9</td>
<td>1.2</td>
<td>1.2</td>
<td>1</td>
</tr>
<tr>
<td>Dayton, OH</td>
<td>-9.55%</td>
<td>-14.83%</td>
<td>9.4</td>
<td>7.7</td>
<td>-3</td>
<td>5.1</td>
<td>5</td>
</tr>
<tr>
<td>Pittsburgh, PA</td>
<td>-10.56%</td>
<td>-8.63%</td>
<td>4</td>
<td>0.1</td>
<td>3.5</td>
<td>-0.3</td>
<td>0</td>
</tr>
<tr>
<td>Rochester, NY</td>
<td>-5.40%</td>
<td>-4.19%</td>
<td>5</td>
<td>3.2</td>
<td>-3</td>
<td>1.1</td>
<td>1</td>
</tr>
<tr>
<td>Jackson, MS</td>
<td>11.07%</td>
<td>-5.83%</td>
<td>6.9</td>
<td>2.6</td>
<td>-1.1</td>
<td>1.3</td>
<td>0</td>
</tr>
</tbody>
</table>

Choose Fall River, MA for case study: local, under-studied, generalizeable
Case study city: Fall River, MA

Flat growth in 1990 – 2000 vs. 5% growth in Bristol County
Higher percentage of foreign-born population than county or state
Data development

- Classify neighborhoods by growth potential:
  - Smart growth: population growth > 2% ($x = 1.5; y = 0.5$)
  - Smart decline: decline > 2%; low-income population, no CDBG investments or both ($x = 0.5, y = 1.5$)
  - Other neighborhoods: ($x = y = 1$)

- Total investment budget equals sum of CDBG and HOME programs ($6,795,162$)
  - Residential-focused growth budget = 80% of total
  - Non-residential-focused growth budget = 20% of total

- Neighborhood-level investment limits are a random percentage of each growth budget:
  - Smart growth: [10%, 30%]; [0%, 10%]
  - Smart decline: [0%, 15%]; [15%, 40%]
  - Other neighborhoods: [5%, 20%] for both
### Fall River dataset

<table>
<thead>
<tr>
<th>Neighborhood</th>
<th>Vacancy Rate</th>
<th>Residential Growth Scale Factor</th>
<th>Nonresidential Growth Scale Factor</th>
<th>Residential Growth Budget</th>
<th>Nonresidential Growth Budget</th>
</tr>
</thead>
<tbody>
<tr>
<td>Maplewood</td>
<td>7.94%</td>
<td>1.5</td>
<td>0.5</td>
<td>$1,475,117</td>
<td>$83,037</td>
</tr>
<tr>
<td>Father Kelly</td>
<td>11.84%</td>
<td>0.5</td>
<td>1.5</td>
<td>$550,538</td>
<td>$506,256</td>
</tr>
<tr>
<td>Merchants</td>
<td>12.05%</td>
<td>0.5</td>
<td>1.5</td>
<td>$570,880</td>
<td>$289,445</td>
</tr>
<tr>
<td>Corky Row</td>
<td>12.65%</td>
<td>0.5</td>
<td>1.5</td>
<td>$883</td>
<td>$265,421</td>
</tr>
<tr>
<td>Flint</td>
<td>11.05%</td>
<td>0.5</td>
<td>1.5</td>
<td>$423,835</td>
<td>$378,268</td>
</tr>
<tr>
<td>Highlands</td>
<td>6.51%</td>
<td>0.5</td>
<td>1.5</td>
<td>$347,764</td>
<td>$263,504</td>
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<tr>
<td>North End</td>
<td>9.01%</td>
<td>0.5</td>
<td>1.5</td>
<td>$626,885</td>
<td>$274,136</td>
</tr>
<tr>
<td>Copicutt</td>
<td>4.80%</td>
<td>1.5</td>
<td>0.5</td>
<td>$707,773</td>
<td>$30,011</td>
</tr>
<tr>
<td>St Anne's</td>
<td>11.58%</td>
<td>1</td>
<td>1</td>
<td>$586,251</td>
<td>$268,226</td>
</tr>
<tr>
<td>Sandy</td>
<td>9.30%</td>
<td>1</td>
<td>1</td>
<td>$393,518</td>
<td>$278,216</td>
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<tr>
<td>Niagra</td>
<td>12.39%</td>
<td>1.5</td>
<td>0.5</td>
<td>$710,111</td>
<td>$43,595</td>
</tr>
<tr>
<td>Lower Highlands</td>
<td>12.54%</td>
<td>0.5</td>
<td>1.5</td>
<td>$654,239</td>
<td>$286,757</td>
</tr>
<tr>
<td>Steep Brook</td>
<td>8.26%</td>
<td>0.5</td>
<td>1.5</td>
<td>$204,029</td>
<td>$369,148</td>
</tr>
<tr>
<td>Bank Street</td>
<td>9.48%</td>
<td>0.5</td>
<td>1.5</td>
<td>$445,975</td>
<td>$228,771</td>
</tr>
<tr>
<td>Below the Hill</td>
<td>12.24%</td>
<td>0.5</td>
<td>1.5</td>
<td>$112,537</td>
<td>$372,555</td>
</tr>
<tr>
<td><strong>Total Budgeted</strong></td>
<td></td>
<td></td>
<td></td>
<td><strong>$7,799,955.00</strong></td>
<td><strong>$3,876,413.00</strong></td>
</tr>
<tr>
<td><strong>Total Available</strong></td>
<td></td>
<td></td>
<td></td>
<td><strong>$5,436,129.60</strong></td>
<td><strong>$1,359,032.40</strong></td>
</tr>
</tbody>
</table>
Model solution

- Premium Solver Platform using Standard LSGRG Nonlinear Engine
- 242 variables and 275 constraints
- Solution times ranged from 8.10 seconds to 32.43 seconds
Value path

- Four of the five non-dominated solutions result in maximum allowable investments across the two investment types.
- Maximizing clustering of investments results in four neighborhoods receiving no investments, and six other neighborhoods receiving no non-residential investments.
Two non-dominated solutions – decision space
Residential investments are concentrated outside of the region containing the CBD

Non-residential investments generally concentrated closer to CBD

Policy recommendation: avoid expensive programs to encourage relocation to the city center via initiatives such as loft redevelopments
Analysis of solutions

- **Tradeoff analysis**
  
<table>
<thead>
<tr>
<th>Metric: Change in neighborhood satisfaction objective associated with one-unit gain in clustering objective</th>
<th>Non-dominated solutions</th>
</tr>
</thead>
<tbody>
<tr>
<td>83,007,583</td>
<td>Optimize neighborhood satisfaction vs. optimize non-residential equity</td>
</tr>
<tr>
<td>817,800</td>
<td>Optimize clustering vs. compromise solution</td>
</tr>
</tbody>
</table>
  
  How does sensitivity to changes in neighborhood satisfaction affect willingness to choose between non-dominated solutions?

- **Greedy heuristic**
  
  - Sort neighborhoods in decreasing order of attractiveness \((1/V_i)\) and decreasing order of residential scale factor \((x)\)
  - Sort neighborhoods in increasing order of attractiveness \((V_i)\) and decreasing order of non-residential scale factor \((y)\)
  - Assign residential (non-residential) investments by ‘bang-for-buck’

  Does ease of generating solution (similar to one that optimizes residential satisfaction) offset resulting inequality?
Conclusions

- Initial effort to provide tangible and substantive guidance to planners and policy-makers
- Solutions balance neighborhood satisfaction, economic efficiency and social equity while accommodating practical limitations on neighborhood-level resource availability
- Neighborhood satisfaction model incorporates notions of scale economies of neighborhood investments while distinguishing between traditional and non-traditional uses
- Non-dominated solutions can serve as a basis for community discussions but not intended to generate specific planning prescriptions
Next steps

- **Current model**
  - Empirically model and validate neighborhood satisfaction functions
  - Investigate alternative forms for equity function
  - Convert decision model to MOLP
  - Engage actual client and allow for different modeling and solution approaches

- **Alternative decision problems**
  - Target individual residential parcels for continued occupancy or allow to become vacant
  - Select vacant parcels for investment for alternative uses
Questions?