Built Environment – Transportation Overview

Daniel A. Rodriguez, Ph.D.

danrod@unc.edu

BEAT Institute, Boston, MA
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Learning objectives

• Identify correlates of the built environment and walking, bicycling, and transit
• Understand challenges in studies of the built environment, transportation, and physical activity
• List and describe basic built environment measures and their challenges
Outline

• Built environment and its correlates with walking, cycling, and transit
• Research challenges
• Measuring the built environment
The built environment

Slide source: Handy, 2011
Upstream built environment determinants

Social determinants of health and environmental health promotion model

Source: Northridge et al, 2003
Upstream built environment determinants

Social determinants of health and environmental health promotion model

Source: Northridge et al, 2003
Socio-ecologic framework

Source: Aytur, 2006
What is the built environment?

- Multidimensional concept
  - Land use patterns – what activities are where
  - Transportation system – how activities are linked
  - Design – how we perceive the places where activities take place and their linkages
- Imageability, legibility, visual enclosure, scale, transparency, linkage, complexity, coherence, tidiness
Importance of design

+ mixed uses and transitional densities
+ low density TOD residential uses fronting street, foliage, improved sidewalks, parking ...
+ ped island, lighting, trees, high density residential development ...
Where would you prefer to walk?
Built Environment < Physical Environment < Environment

- Land use patterns – what activities are where
- Transportation system – how activities are linked
- Design – how we perceive the places where activities take place and their linkages
- Natural Landscape – trees, grass, water, etc.
- Human use – other people and what they are doing

Adapted from Handy, 2011
Walking, bicycling, and transit use
What factors explain walking, bicycling, and public transit as modes of transportation?

**Individual Factors:**
Age, gender, attitudes, experience, comfort?

**Social Support Factors:**
Family, friends, neighbors, crime?

**Physical Environment Factors:**
Sidewalks, crosswalks, land-use mix, proximity, design?

Adapted from Handy, 2011
Why public transit?

• Transit users
  – Nationwide, 29% of them are physically active > 30 minutes/day solely by walking to stops
  – Take 30% more steps and walk 8/min more/day than non users
  – Enjoy lifetime savings of $5,500/person, or higher
Why public transit?

• Light rail in Charlotte, NC
  – Before & after survey
  – Users were 81% less likely to become obese over time
  – BMI went down by 1.18 units (for a given person, ~ 6 lbs)  Source: McDonald et al, 2010
Local infrastructure

• Off-road trails and greenways
  – Living near trails and using trails, related to meeting activity guidelines, higher bicycling
  – For every $1 invested in trails, return of $2.94
  – Important for low income populations


Source: http://lavidaesloca.wordpress.com/category/cali/
Local infrastructure

• Bicycle lanes
  – Across cities, 1% higher lanes related to 0.3% higher bicycling to work Dill 2003; Pucher and Buehler, 2011
  – On-road lanes reduce cyclist crash risk by 50%
Local infrastructure

• Bicycle lanes

• Safety for other users
  – As the number of cyclists and walkers increase, crash risk decreases
  • Doubling cyclists decreases personal risk by 66% (Elvik, 2009; Jacobsen, 2003)
  – Intersection, city, and national levels


Source: Payton Chung. (September 4, 2007) Bicycle boulevard 1. In Flickr.
Local infrastructure

• Sidewalks
  – Review of 16 studies: Having sidewalks \(\rightarrow\) 20 percent more likely to be physically active
  – Study of 11,500 participants in 11 countries
    • Sidewalks in most streets, 47% more likely to meet physical activity guidelines

![Graph showing the relationship between presence of sidewalks and percentage of people who walk. Source: Rodriguez, 2009](image-url)
Local infrastructure

• Calming local traffic
  – High traffic deters from activity (across ages)
  – Crosswalks & traffic management around schools linked to more walking and less being driven to school
  – Calmed traffic $\rightarrow$ 11-15% lower pedestrian crash rates
Road diets
Road diets
Street design
Connectivity benefits

Source: Glatting Jackson Kercher Anglin, Inc.
Evidence regarding associations between the built environment and transportation walking

<table>
<thead>
<tr>
<th>Feature</th>
<th>Score</th>
</tr>
</thead>
<tbody>
<tr>
<td>Density</td>
<td>+</td>
</tr>
<tr>
<td>Land-use mix</td>
<td>+</td>
</tr>
<tr>
<td>Distance to destinations</td>
<td>-</td>
</tr>
<tr>
<td>Pedestrian infrastructure</td>
<td>Emerging</td>
</tr>
<tr>
<td>Street connectivity</td>
<td>Emerging</td>
</tr>
<tr>
<td>Traffic</td>
<td>Insufficient</td>
</tr>
<tr>
<td>Personal safety</td>
<td>Insufficient</td>
</tr>
<tr>
<td>Parks/open space</td>
<td>Insufficient</td>
</tr>
<tr>
<td>Aesthetics</td>
<td>Insufficient</td>
</tr>
</tbody>
</table>

Expanded from Saelens and Handy, 2008
## Built environment and walking

<table>
<thead>
<tr>
<th>Density</th>
<th># of studies</th>
<th>Average elasticity of probability of walking, given a trip</th>
<th># of studies</th>
<th>Average elasticity of # of walking trips</th>
</tr>
</thead>
<tbody>
<tr>
<td>Population</td>
<td>7</td>
<td>0.15</td>
<td>4</td>
<td>0.06</td>
</tr>
<tr>
<td>Jobs</td>
<td>3</td>
<td>0.04</td>
<td>--</td>
<td>--</td>
</tr>
<tr>
<td>Diversity</td>
<td>10</td>
<td>0.22</td>
<td>12</td>
<td>0.16</td>
</tr>
<tr>
<td>Connectivity</td>
<td>4</td>
<td>0.33</td>
<td>2</td>
<td>0.62</td>
</tr>
</tbody>
</table>

Adapted from Ewing and Cervero 2010
Walking to store vs. distance

Source: Handy, Cao, and Mokhtarian, 2006
Walking to store vs. distance

Controlling for age, vehicle ownership, family composition

Source: Shay et al 2006
# Built environment and transit

<table>
<thead>
<tr>
<th></th>
<th># of studies</th>
<th>Average elasticity of probability of transit, given a trip</th>
</tr>
</thead>
<tbody>
<tr>
<td><strong>Density</strong></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Population</td>
<td>12</td>
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</tr>
<tr>
<td>Job</td>
<td>4</td>
<td>0.03</td>
</tr>
<tr>
<td><strong>Diversity</strong></td>
<td>8</td>
<td>0.16</td>
</tr>
<tr>
<td><strong>Design</strong></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Intersection/ street density</td>
<td>3</td>
<td>0.19</td>
</tr>
<tr>
<td>% 4-way intersections</td>
<td>4</td>
<td>0.44</td>
</tr>
<tr>
<td><strong>Distance to transit</strong></td>
<td>3</td>
<td>0.29</td>
</tr>
<tr>
<td>Distance to nearest transit stop</td>
<td></td>
<td></td>
</tr>
</tbody>
</table>

Adapted from Ewing and Cervero 2010
Evidence regarding associations between the built environment and transportation cycling

<table>
<thead>
<tr>
<th>Factor</th>
<th>Status</th>
</tr>
</thead>
<tbody>
<tr>
<td>Trails</td>
<td>Emerging</td>
</tr>
<tr>
<td>Density</td>
<td>Insufficient</td>
</tr>
<tr>
<td>Land-use mix</td>
<td>Insufficient</td>
</tr>
<tr>
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<tr>
<td>Street connectivity</td>
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<td>Bicycle infrastructure</td>
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Adapted from Saelens and Handy, 2008
Outline

• Built environment and its correlates with walking, cycling, and transit

• Research challenges

• Measuring the built environment
Challenges

• Four challenges raised
  1. Attitudes
  2. Self-selection/selective migration
  3. Substitution of PA
  4. Measurement
Challenge 1 – Attitudes

• Attitudes are important
  – Attitudes ≠ perceptions
  – Attitudes help determine how people move in space
  – Attitudes are not exogenous
Challenge 2 – Self-selection

• What if attitudes (partially) determine where you live?
  – It’s the attitudes towards walking, not the environment (some would say)
  – Also called “selective migration”
  – Not mitigated with longitudinal studies
  – Self-selection is a planning opportunity, and a scientists challenge
# Self-selection evidence

<table>
<thead>
<tr>
<th>Effects Found</th>
<th>Number of Studies</th>
</tr>
</thead>
<tbody>
<tr>
<td>Built Environment No Self-Selection</td>
<td>1</td>
</tr>
<tr>
<td>Built Environment AND Self-Selection</td>
<td>15</td>
</tr>
<tr>
<td>Built Environment (Self-Selection Controlled)</td>
<td>11</td>
</tr>
<tr>
<td>Built Environment &gt; Self-Selection</td>
<td>8</td>
</tr>
<tr>
<td>Built Environment &lt; Self-Selection</td>
<td>2</td>
</tr>
</tbody>
</table>

Source: Cao, Mokhtarian, and Handy, 2009
Challenge 3 – Physical activity substitution

- If environmental interventions make it easier to be active in a given place, does overall activity increase? Or does it replace other activity?
  - Potential explanation for some null findings
Physical activity substitution

• More studies showing overall gains in PA for those in activity-friendly areas
  – NQLS study (Sallis et al 2009; Van Dyck et al, 2009a)
  – Montgomery County study
    • Differences between urban residents (relative to exurban)
      – More walking time for transportation
      – More walking trips
      – More within-neighborhood walking trips
    • 1 % increase in home neighborhood ped friendliness → 0.65% more PA in home; 022% less PA elsewhere
Challenge 4 – Measurement

- Different uses of measuring the built environment
  - E.g., research, evaluation, policy-making
  - May require also measuring where physical activity occurs

- Worry about
  - What to measure
  - Where to measure it
  - How to measure
Outline

• Built environment and its correlates with walking, cycling, and transit
• Research challenges
• Measuring the built environment
Where & what: Matching exposures and behaviors

Overall BE

BE at Home
BE in Nbhd
BE at Work
BE at School
BE elsewhere

PA at Home
PA in Nbhd
PA at Work
PA at School
PA elsewhere

Total PA

Adapted from: Handy, 2011
Where & what: Matching exposures and behaviors

- Sidewalks
- Bike lanes
- Trails
- Courts

BE in nbhd

- Walking
- Biking
- Jogging
- Basketball

PA in nbhd

Slide from: Handy, 2011
Where & what: Matching exposures and behaviors

BE in nbhd

Distance to stores
Sidewalks
Traffic levels
Landscaping

Walking for travel

Walking for exercise

Walking in nbhd

Adapted from: Handy, 2011
How?

• Sources of data
  – Secondary data (eg collected by federal, state, regional agency)
    • Jobs: Metropolitan planning organization
    • Income/poverty: ACS (note pooling and error)
    • Population: Census Bureau, State Demographer
How? Population density

Examples of what to calculate from it:

• Gross population density per unit of area
• Net population density per unit of area (net of...?)
• Population density in residential areas (requires pareels...)
How?

• Sources of data
  – Secondary data
  – Primary data
    • Fieldwork: Counts, audits
    • Expert input
    • Resident or neighbor survey (self-reports)

Neighborhood Environment Walkability Scale (NEWS)

We would like to find out more information about the way that you perceive or think about your neighborhood. Please answer the following questions about your neighborhood and yourself. Please answer as honestly and completely as possible and provide only one answer for each item. There are no right or wrong answers and your information is kept confidential.

A. Types of residences in your neighborhood
Among the residences in your neighborhood…

1. How common are detached single-family residences in your immediate neighborhood?
   
<table>
<thead>
<tr>
<th></th>
<th>1</th>
<th>2</th>
<th>3</th>
<th>4</th>
<th>5</th>
</tr>
</thead>
<tbody>
<tr>
<td>None</td>
<td>A few</td>
<td>Some</td>
<td>Most</td>
<td>All</td>
<td></td>
</tr>
</tbody>
</table>

2. How common are townhouses or row houses of 1-3 stories in your immediate neighborhood?

<table>
<thead>
<tr>
<th></th>
<th>1</th>
<th>2</th>
<th>3</th>
<th>4</th>
<th>5</th>
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</thead>
<tbody>
<tr>
<td>None</td>
<td>A few</td>
<td>Some</td>
<td>Most</td>
<td>All</td>
<td></td>
</tr>
</tbody>
</table>
### How? (secondary data)

<table>
<thead>
<tr>
<th>Feature</th>
<th>Level</th>
</tr>
</thead>
<tbody>
<tr>
<td>Land Use</td>
<td>High</td>
</tr>
<tr>
<td>Transportation</td>
<td>High</td>
</tr>
<tr>
<td>Design</td>
<td>Low</td>
</tr>
<tr>
<td>Natural landscape</td>
<td>Medium</td>
</tr>
<tr>
<td>Human use</td>
<td>Low</td>
</tr>
</tbody>
</table>

Adapted from: Handy, 2011
How? (field audits)

• Environmental audits to collect data commonly unavailable as secondary data
  – Infrastructure (lockers, racks, benches, etc.)
  – Sidewalk quality
    • Maintenance status, material, distance from road, from adjacent land uses (setbacks)
  – Incivilities
  – Enclosure
  – Scale
Audit aggregation for research

Characteristics of street segments

<table>
<thead>
<tr>
<th>Segment</th>
<th>Sidewalks</th>
<th>Public transit</th>
</tr>
</thead>
<tbody>
<tr>
<td>1</td>
<td>2 sides</td>
<td>yes</td>
</tr>
<tr>
<td>2</td>
<td>1 side</td>
<td>no</td>
</tr>
<tr>
<td>3</td>
<td>2 sides</td>
<td>no</td>
</tr>
<tr>
<td>4</td>
<td>0 sides</td>
<td>no</td>
</tr>
</tbody>
</table>

Neighborhood characteristics by household

<table>
<thead>
<tr>
<th>Household</th>
<th>Sidewalks w/in ¼ mile</th>
<th>Public transit w/in ¼ mile</th>
</tr>
</thead>
<tbody>
<tr>
<td>1</td>
<td>0.5</td>
<td>no</td>
</tr>
<tr>
<td>2</td>
<td>0.75</td>
<td>yes</td>
</tr>
<tr>
<td>3</td>
<td>0.8</td>
<td>no</td>
</tr>
<tr>
<td>4</td>
<td>0.6</td>
<td>no</td>
</tr>
</tbody>
</table>

Source: Handy, 2011
Audit aggregation for evaluation
Audit aggregation for evaluation
How: GIS - In General

Existing data in GIS layers

Neighborhood characteristics for households or zones to calculate

Population distribution

Residential density

Parcel data on land use

Land use mix

Street network

Distance to: nearest store, park

Transit network

Connectivity

Bus transit

Adapted from: Handy, 2011
## How? Data sources and GIS

<table>
<thead>
<tr>
<th>Data Source</th>
<th>Role of GIS</th>
</tr>
</thead>
<tbody>
<tr>
<td>Existing data</td>
<td>Derive measures</td>
</tr>
<tr>
<td></td>
<td>Sampling</td>
</tr>
<tr>
<td>Field audits</td>
<td>Manage data</td>
</tr>
<tr>
<td></td>
<td>Derive measures</td>
</tr>
</tbody>
</table>

Source: Handy, 2011
What? Revisited

• Deriving measures from GIS
  – Intensity/density
  – Land use mixture/diversity
  – Destinations/disaggregate land uses
  – Street design and directness
  – Distance to transit
I.P.E.N.

• International Physical Activity and the Environment Network

• Aims to:
  – Increase communication/collaboration on envr. correlates of physical activity
  – Recommend common methods and measures

• Includes 12 countries:

• [http://www.ipenproject.org/index.html](http://www.ipenproject.org/index.html)
IPEN GIS templates

- [http://www.ipenproject.org/documents/methods_docs/IPEN_GISTEMPLATES.pdf](http://www.ipenproject.org/documents/methods_docs/IPEN_GISTEMPLATES.pdf)

<table>
<thead>
<tr>
<th>Table of Contents</th>
</tr>
</thead>
<tbody>
<tr>
<td>1. Template Instructions</td>
</tr>
<tr>
<td>2. Variable Naming Instructions</td>
</tr>
<tr>
<td>3. Neighborhood Buffers</td>
</tr>
<tr>
<td>4. Residential Density and Land Use</td>
</tr>
<tr>
<td>5. Commercial/Retail Land Use</td>
</tr>
<tr>
<td>6. Civic and Institutional Land Use</td>
</tr>
</tbody>
</table>
A note on land use mixtures

• Entropy frequently used
  – 9/22 studies in Ewing and Cervero 2010
  – Evenness of distribution of land uses

\[
\{-\sum_{i=1}^{s} p_i \ln(p_i)\}
\]

– \(p_i\) are proportions of developed land for each of the \(S\) land use types
  • SFR, MFR, Commercial, Industrial, Public institutional and Park uses
  – Ranges from 0 to infinity
A note...

• Comments on entropy
  – Various uses simultaneously
  – Increases with $s$ and evenness
    • Solution: Normalize by $\ln(s)$

$$\left\{-\sum_{i=1}^{s} p_i \ln(p_i)\right\} / \ln(s)$$

• Ranges from 0 to 1
  – 0 = Dominance of one use
  – 1 = Uses evenly distributed within analysis unit
A note...

• Comments on entropy
  – Checkerboard pattern same as clustered pattern
  • When analysis unit is large, this is important

• Entropy is 1 in the three cases
A note...

• Comments on entropy (cont.)
  – If analysis unit size varies, small areas less likely to have diverse uses
    • Solution: spatial average within distance buffer
  – Not sensitive to relative distribution
    • 90% Residential 10% other, or vice versa
  – WHY IS EVENNESS GOOD? DOES IT MEAN ANYTHING?
  – Smaller units, more homogenous (MAUP)
A model for change: Co-benefits
A view from transportation

- Co-benefits are key
  - Environment
    - Climate change
    - Air quality
    - Water quality
  - Social
    - Health and safety
    - Cost of housing
    - Transportation costs
Environmental Benefits

- Motor vehicle emissions in the US:
  - 31 percent of total carbon dioxide
  - 81 percent of carbon monoxide
  - 49 percent of nitrogen oxides
- Air pollution contributes to 70,000 deaths nationwide each year; affects greenhouse gases and climate change
- Shorter car trips are more polluting on a per-mile basis than longer trips
- A short, four-mile round trip by bicycle keeps about 15 pounds of pollutants out of the air we breathe

Source: Clean Air Council, League of American Bicyclists, WorldWatch Institute, Harvard School of Public Health, Federal Highway Administration
Land consumption

• Impervious surface cover decreases
  – Heat island
  – Water quality and quantity
• Allows for local greenspace/farmland preservation
• Mental health implications

Source: AAA, US Census surveys
Economic benefits

• Personal Economics
  – The cost of operating a sedan for one year is approximately $7,834
  – Ownership of one motor vehicle accounts for more than 18 percent of a typical household's income
  – Non-motorized transportation is affordable

Source: AAA, US Census surveys
Urban form benefits

Source: Bob Schneider, UC Berkeley; Press Office, City of Muenster, Germany
Learning objectives

• Identify correlates of the built environment and walking, bicycling, and transit
• Understand challenges in studies of the built environment, transportation, and physical activity
• List and describe basic built environment measures and their challenges
Thank you!
Appendix

• List of measures
  – From Handy, S. 2011 BEAT Institute Slides.
TRB-IOM Review

- 22 Travel behavior studies
  - 31 measures of active travel
  - 50 measures of the built environment
- 28 Physical activity studies
  - 23 measures of physical activity
  - 42+ measures of the built environment

Measures of Land Use
identified in Handy 2005

- Population density
- Employment density
- Retail density
- Land use mix
- Land use diversity factor
- Land use balance
- Rating of land use, density, and urban form

- Indicator of mixed-use or not
- Indicator of high density or not
- Amount of single-family housing within 300 feet
- Ratio of single-family housing to multifamily housing within 300 feet
Measures of Transportation
identified in Handy 2005

• Percent of network that is grid
• Street density
• Pedestrian Environment Factor
• Indicator for presence of sidewalks
• Indicator for presence of bike paths
• Percent of streets with sidewalks
• Average sidewalk width
• Pedestrian-/Bike-friendly design
Measures of Perceived Accessibility
identified in Handy 2005

- Access to facilities or places (y/n)
- Access to local shopping (2 items)
- Places within walking distance (y/n)
- Convenience to facilities (y/n or 5 point scales, multiple items)
- Physical activity related opportunities (5 point scale)
- Places to exercise (y/n)
- Number of places to exercise
- Places to walk (y/n)
- Exercise equipment at home (y/n or number of items)
- Worksite environment (10 items)
- Satisfaction with recreation facilities (5 point scale) or adequacy of facilities (y/n)
- Satisfaction with neighborhood services (2 items)
- Distance from bikeway, steep hill, busy street to cross
- Ease of walking to transit stop (1 item)
Measures of Neighborhood Type
identified in Handy 2005

- Traditional vs. suburban
- Transit vs. automobile
- Traditional vs. planned-unit development
- Pedestrian-oriented vs. automobile-oriented
- Urban vs. suburban
- LADUF rating
- Traditional factor
- Suburban factor
Neighborhood Characteristics –
11 Studies starting with Sallis
identified in Handy 2005

- Sidewalks (y/n)
- Heavy traffic (y/n)
- Hills (y/n)
- Streetlights (y/n)
- Unattended dogs (y/n)
- Enjoyable scenery (y/n)
- Frequently see others exercising (y/n)
- High levels of crime (y/n)