Mode Choice and Urban Form

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Introduction

The table below shows transit’s share in the urban US (all trip purposes) and the 10 urban areas where it is most popular (2008 data):

<table>
<thead>
<tr>
<th>Area</th>
<th>Share (%)</th>
</tr>
</thead>
<tbody>
<tr>
<td>Urban US</td>
<td>1.6</td>
</tr>
<tr>
<td>New York</td>
<td>11.0</td>
</tr>
<tr>
<td>San Francisco</td>
<td>5.0</td>
</tr>
<tr>
<td>Washington DC</td>
<td>4.5</td>
</tr>
<tr>
<td>Chicago</td>
<td>3.9</td>
</tr>
<tr>
<td>Honolulu</td>
<td>3.8</td>
</tr>
<tr>
<td>Boston</td>
<td>3.3</td>
</tr>
<tr>
<td>Seattle</td>
<td>2.8</td>
</tr>
<tr>
<td>Philadelphia</td>
<td>2.7</td>
</tr>
<tr>
<td>Portland</td>
<td>2.3</td>
</tr>
</tbody>
</table>

Transport planners must face the fact that very few trips in US urban areas use transit — most are made by car.
The problem

Many urban planners regard this as a serious problem.
They believe people should be making fewer trips by car, and more using transit, or by walking.
(For a case that they are wrong, see Winston and Shirley (1998)).
But given that we think there is a problem here, what can we do about it?
How can we encourage more people to use transit?
We can think of two possible approaches here.
The Transportation Planner’s Approach

The transportation planner focuses on characteristics of the transportation modes.

- Transit’s characteristics could be made more attractive: for example, its fares could be reduced or its frequencies or degree of coverage of an urban area could be raised. But this is likely to run into another problem: it will cost money, most urban areas are unwilling to increase the already substantial subsidies paid to transit.

- Alternatively, auto users could be made to face the full costs of their actions, including the impacts that their decisions have on others. This leads to the idea of congestion tolls, and it would certainly make auto usage less attractive. But it is not clear that a system of congestion tolls could be made to work: it is difficult to implement on arterial roads, and even on limited-access expressways it would be politically unpopular.
The Urban Designer’s Approach

If changing transportation characteristics is out, is there another way?

- Many planners and urban designers are drawn to a second possibility: can we make the built structure of urban areas more conducive to non-auto use?
- This is to ask whether *urban form* has a significant impact on an individual’s mode choices.
- This second strategy is what we will study here: to what extent can urban form affect mode-choice decisions?
- But first we need to understand how transportation planners study individuals’ mode choice decisions themselves.
- See separate handout.
The Study

We now return to our main thread, the impact of urban form on mode-choice decisions.

- I will discuss a study by Michael Reilly and John Landis (see References) that attempts to find the impact of urban form on mode choice.
- Study area: San Francisco Bay Area.
- Study date: 1996, using data from the Bay Area Travel Survey.
- Behavior: non-work trips only.
- Survey: respondents 16 years of age or older.
The Bay Area is well served by diverse transit modes:

- **San Francisco area**: commuter rail (SP); heavy rail (BART), bus, trolleycar, cable car (MUNI); demand-responsive.
- **East Bay**: heavy rail (BART), bus (AC Transit), demand-responsive.
- **Marin County**: bus, ferryboat (GG Transit).

It also has a good — if highly congested — network of roads.
Mode shares for home-based non-work trips by persons 16 years of age and older:

<table>
<thead>
<tr>
<th>Mode</th>
<th>No. trips</th>
<th>% trips</th>
</tr>
</thead>
<tbody>
<tr>
<td>Drive</td>
<td>7,915</td>
<td>77.1</td>
</tr>
<tr>
<td>Transit</td>
<td>461</td>
<td>4.5</td>
</tr>
<tr>
<td>Walk/Bicycle</td>
<td>1,893</td>
<td>18.4</td>
</tr>
<tr>
<td>All modes</td>
<td>10,269</td>
<td>100.0</td>
</tr>
</tbody>
</table>
Most planners agree that the influence of urban form should be exerted primarily in an individual’s local neighborhood.

But what is a neighborhood? How far does a residence’s neighborhood extend?

Reilly and Landis consider a given house’s neighborhood to be a circular area around the house, and consider neighborhoods of radius 1/4 mile, 1/2 mile, 1 mile and 4 miles.

Most of the urban form variables to be considered here are defined for each of these neighborhoods.
The region was first divided into grid cells $100m \times 100m$.

So the area of each cell was 1 hectare (10,000 square meters).
For each urban form descriptor, for example street intersections, its location was superimposed on the grid.
For each respondent in the sample, his or her origin (home) location (X) was known.

Circular neighborhoods were then constructed around this home.

The number of cells containing the feature of interest was counted.

Presumably some method was developed for overlaps; but the paper does not describe them.
Urban Form Descriptors

We now describe more detail the urban form descriptors used by Reilly and Landis.

- For each of them we indicate why they might be expected to affect mode choice decisions, and how they were computed.
- Remember as we examine these, that we are considering non-work trips (roughly, shopping trips or trips for entertainment) only. Work trips are not included in the analysis.
- Though the authors are interested in transit, it appears that the primary rationale for inclusion of the variables was the expected impact on walking.
- The variables used in the study represent a trade-off between what is hypothesized to be (possibly) relevant, and which is actually computable from available data.
Residential Population Density

- **Rationale**: in the literature, higher population densities seem to be associated with an increased retail and service variety, and with shorter — more walkable — distances. On the other side, parking is likely to be more difficult in high-residential density areas, which will also make walking more attractive (also, some forms of transit).

- **Measurement**: The authors measured population density as
  
  \[
  \text{Density} = \frac{\text{residents}}{\text{residential land area}} / \text{census block}
  \]
  
  for each of the 4 neighborhood definitions.
Commercial Accessibility

- **Rationale:** The literature supports a connection between access to retail land use, shopping frequency and mode choice. If you live near diverse shopping opportunities you are more likely to make shorter — often walk — trips. On the other hand, if commercial activity is far away from the individual’s location, trips tend to be chained, meaning that an individual will tend to satisfy many different goals in a single trip; and this in turn will tend to favor auto trip-making.

- **Measurement:** The authors used two measures of commercial accessibility
  - The straight-line distance to the nearest hectare of commercial land use. This did not vary by neighborhood definition.
  - The proportion of the land use within each house’s neighborhood that is zoned commercial.
Land Use Heterogeneity

- **Rationale**: The more heterogeneous (ie diversified) local land use is, the more it is conducive to non-auto trips. A good mix of residential/commercial land use encourages these kinds of trips. If block after block is basically the same, people will tend to use cars (possibly transit) to avoid the monotony.

- **Measurement**: The authors constructed two measures of heterogeneity:
  - A land-use dissimilarity measure for adjacent grid cells.
  - A measure like the first, in which they omitted open space.
Housing Stock Diversity

- **Rationale**: This is another way that land uses can be more varied (which will encourage walking). Neighborhoods dominated by larger single-family detached homes are thought to be more conducive of auto use, possible because they tend to be associated with higher income individuals.

- **Measurement**: Housing stock diversity was measured as the proportion of detached single-family houses in the neighborhood.
Average Block Size

- **Rationale**: shorter blocks make for easier pedestrian navigation, and hence encourage walking.
- **Measurement**: Average block area for each neighborhood definition.
Intersection Density

- **Rationale**: The impact here is hard to assess. On the one hand, the greater the density of street intersections, the easier it is for pedestrians to navigate around the area. On the other hand, the more intersections there are to be crossed, the more opportunities you have to be run down by cars, and this might inhibit walking. If transit routes tend to place stops at busier intersections, then the more intersections, the more stops. This could also cut both ways: it makes transit access easier, but on the other hand, for people already on board, it makes trips longer.

- **Measurement**: Number of intersections per square kilometer.
Average Parcel Size

- **Rationale**: smaller parcel (lot) sizes are likely to be more diverse, i.e. visually interesting, and hence encourage walking.
- **Measurement**: average parcel size.
Visual Heterogeneity

- **Rationale**: the more visually heterogeneous a neighborhood is, the more interesting the trip itself is likely to be; and this may encourage walking. On the other hand, the less heterogeneity is present, the trip itself will be less interesting, and this encourages non-walking modes.

- **Measurement**: Given the modern tendency towards mass-produced houses, heterogeneity was thought to be associated with an older housing stock. Hence it was proxied by the median year that neighborhood houses were built.
# Data Summary

Means and standard deviations for the variables in 1/4 and 1-mile neighborhoods

<table>
<thead>
<tr>
<th>Concept</th>
<th>Variable</th>
<th>Neighborhood</th>
<th>1/4-mile</th>
<th>1-mile</th>
</tr>
</thead>
<tbody>
<tr>
<td>Population density</td>
<td>Population density</td>
<td>36.7</td>
<td>39.5</td>
<td></td>
</tr>
<tr>
<td>Comm. accessibility</td>
<td>Prop. comm. land use</td>
<td>0.095</td>
<td>0.151</td>
<td>0.100</td>
</tr>
<tr>
<td>Comm. accessibility</td>
<td>Dist to comm. l-u (*)</td>
<td>0.567</td>
<td>0.151</td>
<td></td>
</tr>
<tr>
<td>Land Use Heter.</td>
<td>Dissimilarity index</td>
<td>0.276</td>
<td>0.226</td>
<td>0.434</td>
</tr>
<tr>
<td>Housing Diversity</td>
<td>Prop.detached housing</td>
<td>0.573</td>
<td>0.302</td>
<td>0.578</td>
</tr>
<tr>
<td>Avg Block Size</td>
<td>Avg Block Size</td>
<td>366.6</td>
<td>1238.4</td>
<td>594.2</td>
</tr>
<tr>
<td>Intersection Density</td>
<td>Intersection Density</td>
<td>0.515</td>
<td>0.252</td>
<td>0.424</td>
</tr>
<tr>
<td>Avg Parcel Size</td>
<td>Avg Parcel Size</td>
<td>0.359</td>
<td>0.604</td>
<td>0.393</td>
</tr>
<tr>
<td>Visual Heterogeneity</td>
<td>Median year housing built</td>
<td>1959.5</td>
<td>14.2</td>
<td>1960.1</td>
</tr>
</tbody>
</table>

(*) : does not vary with neighborhood size
Logit vs Conditional Logit (I)

- In our discussion of mode choice, we referred to the logit model.
- This was a model in which each characteristic of a mode (e.g., the cost or fare) had the same weight ($\beta$ factor) for the individual. This is the logit model as the term is used in the transportation literature.
- There is a second form of the model in which each mode has its own individual set of weights: in this case there would be, for example, a $\beta$-weight for auto cost, a different $\beta$-weight for transit costs etc.
- Outside the transportation literature, this model is usually referred to as the logit model, while the first kind of model is called the conditional logit model.
- In the mode-specific $\beta$-weights case, it turns out that the all weights for one of the modes must be set equal to zero: for Reilly and Landis, these are taken to be the weights for the auto choice.
Logit vs Conditional Logit (II)

- In terms of our logit discussion, suppose that the systematic utility for individual \( i \) and mode \( j \) is given by

\[
\nu_{ij} = \beta_{j1} x_{i1} + \beta_{j2} x_{i2} + \cdots + \beta_{jK} x_{ik}
\]

— note that the \( x \)'s do not vary by mode \((j)\), and that the coefficients \((\beta \)'s) do.

- Example: take \( x_{i1} \) to be the neighborhood housing stock diversity (ie the proportion of detached single-family houses) in individual \( i \)'s neighborhood.

- This will be the same for all modes in individual \( i \)'s choice set. The form of the logit model shown above gives the characteristic one weight for the utility achieved for the first mode, and a different weight for the second mode, etc.

- Hence the \( \beta \)'s have weights that depend on the mode \((j)\) while the characteristics (the \( x \)'s) do not.
The logit model still has the familiar form

\[ P_{ij} = \frac{e^{v_{ij}}}{\sum_m e^{v_{im}}} \]

except now we normalize on mode 1 by setting all the \( \beta \)'s for this mode equal to zero. The result is:

\[ P_{ij} = \frac{e^{v_{ij}}}{1 + \sum_{m \neq 1} e^{v_{im}}} \]
[blank slide]
See opposite for notes and details.

<table>
<thead>
<tr>
<th>Concept</th>
<th>Variable</th>
<th>walking</th>
<th>sig</th>
<th>transit</th>
<th>sig</th>
</tr>
</thead>
<tbody>
<tr>
<td>Population density</td>
<td>Population density (†)</td>
<td>0.006</td>
<td>*</td>
<td>0.007</td>
<td>*</td>
</tr>
<tr>
<td>Comm. accessibility</td>
<td>Prop. comm. land use</td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Comm. accessibility</td>
<td>Dist to comm. l-u (‡)</td>
<td>−0.325</td>
<td>**</td>
<td>0.354</td>
<td>*</td>
</tr>
<tr>
<td>Land Use Heter.</td>
<td>Dissimilarity index</td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Housing Diversity</td>
<td>Prop.detached housing</td>
<td>−1.413</td>
<td>*</td>
<td>−0.891</td>
<td>**</td>
</tr>
<tr>
<td>Avg Block Size</td>
<td>Avg Block Size</td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Intersection Density</td>
<td>Intersection Density</td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Avg Parcel Size</td>
<td>Avg Parcel Size</td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Visual Heterogeneity</td>
<td>Median year housing built</td>
<td>−0.028</td>
<td>**</td>
<td>−0.017</td>
<td>*</td>
</tr>
</tbody>
</table>
Basic Results: Details

- The model is for all non-work trips. Observations: 7604.
- The many available modes in the SFBA were collapsed to three: auto, transit (all forms), walking
- Models include individual-specific variables for eg whether the individual had a driver’s licence, his or her race, whether employed, etc. Results for these variables are not shown in the table opposite.
- Significance levels: (***): < 1% ; (**) : 5% ; (*): 10%.
- Variables with no entries in the table opposite were found to be insignificant, or so highly correlated with significant results as to preclude identification of the coefficients.
- Neighborhoods: (†): 1 mile; (‡): 1/2-mile
First question: does urban form matter at all for mode choice?

- We can answer this by comparing a mode-choice model including urban form variables with one that does not.
- Including the urban-form variables raises the pseudo-$R^2$ (i.e., McFadden’s $\rho$) from 0.185 to 0.237 over a model that does not include them.
- So yes, adding the urban form variables does add something to our understanding of mode choice.
- But even the higher pseudo-$R^2$ is not considered particularly good in the discrete-choice literature. One would be reluctant to take these models as good predictors of mode choice behavior.
Second question: which urban form variables matter?

- It turns out that very few of the urban-form variables were significant, even at the 10% level.
- If one focuses only those that were significant at the 5% level or better, then
  - for walking: only the distance to the nearest commercial land-use and a measure of housing heterogeneity matter.
  - for transit, only the proportion of neighborhood houses that are detached matters

- The mode-choice results for transit seem a little suspect to me, since they do not include any of transit’s characteristics: the fare, whether or not the mode is accessible etc. Most mode-choice models would include these (as in our examples in the mode choice handout).
Still, let’s take the results at face value and ignore the statistical-significance issue.

We can ask: how does changing the levels of these variables change the probabilities of walking or taking transit?

To answer this, let’s set all the variables at their sample-mean levels, vary one of the urban form, and record the probabilities of taking transit or of walking.

The next slides show some results. These are from Figure 12 of the Reilly and Landis paper.

Though it’s a little hard to see, the vertical scale is probability, starting from zero, in 5% increments (the horizontal lines).
Population Density

- 1-mile neighborhood.
- For both modes, increasing density increases the probability of walking and taking transit.
- Transit (lower, dashed curve): impact is quite small: to get a serious improvement one would need to increase density by a lot.
- Walking (upper, solid curve): impact is greater, but again we would need a very large increase.
As the nearest commercial parcel gets further away, the probability of walking there goes down (solid curve). Extrapolating, if we start with the nearest site 2.5 miles away, reducing the distance by 1 mile adds about 1% to the walking probability.

Conversely, the probability of using transit goes up (dashed curve). Adding 1 mile to distance (at 2.5 miles) adds perhaps 1% to the transit probability.
Visual heterogeneity has a negligible impact on transit, as we’d expect.

For walking it is more substantial.

Consider a neighborhood where the median house was built in 1964. As compared with a newer neighborhood (median age 1969) we seem to add about 1% to the walking probability.
This also has a negligible impact on transit, as we’d expect.

As the proportion of detached houses rises from 10% to 20% the probability of walking seems to fall by about 2%.

When the proportion rises from 80% to 90% the impact is about 1%.
Some Tentative Conclusions

- This research appears to show that changes in urban form cannot be expected to have major impacts on individuals’ decisions to use transit or to walk, for non-work trips.
- So the transportation planner’s difficulty remains: how to get people out of their cars?
- However, this is an active area of research, and there is a lot to be done. For example, could we think of other measures of urban form that this research did not consider; and can we assess whether they are important in mode choice?
References

Michael Reilly and John Landis.
“The influence of built-form and land use on mode choice”.

Clifford M. Winston and Chad Shirley.
Alternate Route: Toward Efficient Urban Transportation.