IMPACT OF BUILT ENVIRONMENT ON FIRST- AND LAST-MILE TRAVEL MODE CHOICE

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First/Last mile issue in Singapore

- Residents in Singapore heavily rely on public transport for daily travels
  - Low auto ownership
  - High cost to own and to use a car
- An obstacle in promoting higher public transit usage
  - Distance to transit station may sometimes be greater than the willingness to walk
- First/Last mile:
Impact of built environment

- In past studies, solutions to bridge the gap tend to redesign the built environment:
  - Altering the location to mixed-used activity centers
  - Siting houses/workplaces near rail stations
  - Constructing pedestrian footways, shaded corridors and bike lanes
- We aim at investigating the impact of the BE on first- and last-mile modal choice
  - We use a mixed logit (ML) framework to capture the heterogeneity of the impact of BE
Data

• Modal choice: Household Interview Travel Survey (Total Sample size: 23,941)
• BE variables: Singapore Land Authority digitized cadastral data
• Employment and resident distribution: Zhu and Ferreira (2014)
• Travel time & travel cost of unselected mode: Google Maps API
Spatial representativeness of the sample
Mode choice

LRT is available

- Walk
- Bus
- LRT (Light Rail)

LRT is unavailable

- Walk
- Bus
First & last mile modal share

Data Source: HITS 2012
Total Sample Size: 23,941

LRT
Walk
Bus
Other
MRT/LRT Line
MTZs

# Samples: 560
Descriptive Analysis

• In Singapore, walk and bus are the two major travel modes for the first- and last-mile trips. Mean travel time is about 7-10 minutes.

| Area                          | Mode  | Modal share (%) |
|-------------------------------|-------|-----------------|
| Area where LRT is unavailable | Walk  | 72.30           |
|                               | Bus   | 26.74           |
|                               | Other | 0.96            |
| Area where LRT is available   | Walk  | 52.74           |
|                               | Bus   | 29.96           |
|                               | LRT   | 15.81           |
|                               | Other | 1.49            |
Built Environment (BE)

- 4 “D” variables (Ewing and Cervero, 2010)
  - 4 “D” variables: Density, Diversity, Design and Distance to transit
  - In 3 categories: Origin area, Destination area, and Non-MRT station area
  - For example:
Mixed Logit (ML) Models

- The mean impact and taste variation of BE
- Variables:
  - Sociodemographic characteristics;
  - BE variables;
  - Trip-specific attributes of each travel mode;
  - Alternative specific constant (ASC)
- The probability of individual $n$ choosing travel mode $i$ can be expressed as

$$P_{ni} = \int \frac{\exp(V_{ni})}{\sum_{k=1}^{K} \exp(V_{nk})} f(\beta) d\beta$$
Model 1: LRT unavailable

| Variable                                      | (a) With BE |          | (b) Without BE |          |
|-----------------------------------------------|-------------|----------|----------------|----------|
|                                               | Coefficient | t-test   | Coefficient    | t-test   |
| **Walk**                                      |             |          |                |          |
| Constant $\alpha$                            | -           | 0        | fixed          | 0        | fixed |
| Travel time                                   | Mean        | -0.567   | -20.06         | ***      | -0.580 | -41.09 | *** |
|                                               | †Std. Dev.  | -0.115   | 0.11           |          | 0.383  | 0.23   |     |
| **Bus**                                       |             |          |                |          |
| Constant $\alpha$                            | -           | -9.510   | -17.25         | ***      | -6.38  | -46.13 | *** |
| Travel time                                   | Mean        | -0.946   | -16.09         | ***      | -0.253 | -21.73 | *** |
|                                               | Std. Dev.   | 0.250    | 12.42          | ***      | 0.058  | 4.97   | *** |
| Commute trip (Yes=1)                         | -           | 0.235    | 1.81           | *        | 0.243  | 3.81   | *** |
| Distance to MRT station                      | †Mean       | 1.160    | 15.95          | ***      | -      | -      |     |
|                                               | ‡Std. Dev.  | 0.102    | 0.04           |          | -      | -      |     |
| EAI to Bus stop (Origin)                     | Mean        | 2.650    | 6.98           | ***      | -      | -      |     |
|                                               | Std. Dev.   | 0.037    | 0.28           |          | -      | -      |     |
| Floor space density (Non-MRT station area)   | Mean        | -0.329   | -4.53          | ***      | -      | -      |     |
|                                               | Std. Dev.   | 0.146    | 3.23           | ***      | -      | -      |     |
| Walking-based EAI to MRT station             | Mean        | -0.039   | -6.43          | ***      | -      | -      |     |
|                                               | Std. Dev.   | 0.027    | 6.81           | ***      | -      | -      |     |
| Road density (Non-MRT station area)          | Mean        | 0.144    | 1.75           | *        | -      | -      |     |
|                                               | Std. Dev.   | 0.362    | 0.06           |          | -      | -      |     |
| Statistics                                    |             |          |                |          |
| Observations                                 | 20181       |          | 20181          |          |
| Rho squared                                  | 0.832       |          | 0.736          |          |
| Adjusted Rho squared                         | 0.831       |          | 0.735          |          |
Summary of Model 1

- Trip-specific variables:
  - Walking time (-)
  - Bus travel time (-, significant $\sigma$)
- With BE, goodness-of-fit increases
- Impact of BE
  - We set walk as benchmark, all in utility function of bus
  - Distance to MRT (+)
  - EAI to bus stop from origin (+)
  - Walk-based EAI to MRT station (-, significant $\sigma$)
  - Floor space density in non-MRT area (-, significant $\sigma$)
  - Road density (+)
## Model 2: LRT available

| Variable                              | (a) With BE                      | (b) Without BE                     |
|---------------------------------------|----------------------------------|------------------------------------|
|                                       | Coefficient | t-test | Coefficient | t-test |
| **Walk**                              |             |        |             |        |
| Constant $\alpha$                     | -           |        | 0 fixed     |        |
| Travel time                           | Mean        | -0.835 | -4.06***    | -1.260 | -6.42*** |
|                                       | †Std. Dev.  | 0.144  | 2.77**      | 0.235  | 4.28***  |
| **Bus**                               |             |        |             |        |
| Constant $\alpha$                     | -           |        | -3.860      | -1.46  | -7.290    | -6.92*** |
| Travel time                           | Mean        | -1.850 | -3.68***    | -0.904 | -5.57*** |
|                                       | Std. Dev.   | 0.392  | 2.99***     | 0.154  | 2.70**   |
|                                       | †Mean       | 2.450  | 3.58***     |         |         |
|                                        | †Std. Dev.  | 1.430  | 0.16        |         |         |
| **Distance to MRT station**           | Mean        | -15.40 | -2.95***    |         |         |
|                                       | Std. Dev.   | 0.439  | 0.34        |         |         |
| **Entropy (Non -MRT station area)**   | Mean        | 3.020  | 2.76**      |         |         |
|                                       | Std. Dev.   | 0.141  | 0.19        |         |         |
| **LRT**                               |             |        |             |        |
| Constant $\alpha$                     | -           |        | 11.90       | 1.43   | -7.790    | -6.35*** |
| Travel time                           | Mean        | -3.230 | -2.71**     | -1.130 | -6.11*** |
|                                       | Std. Dev.   | 0.540  | 2.29**      | 0.008  | 0.11     |
|                                       | †Mean       | 3.250  | 2.69**      |         |         |
|                                        | †Std. Dev.  | 0.032  | 0.23        |         |         |
| **Entropy (Non -MRT station area)**   | Mean        | -44.40 | -2.38**     |         |         |
|                                       | Std. Dev.   | 3.600  | 1.73*       |         |         |

**Statistics**

|               | (a)          | (b)          |
|---------------|--------------|--------------|
| Observations  | 2373         | 2373         |
| Rho squared   | 0.891        | 0.816        |
| Adjusted Rho squared | 0.885    | 0.813        |
Summary of Model 2

• Trip specific variables
  • Walking time (-0.8, significant $\sigma$)
  • Bus travel time (-1.9, significant $\sigma$)
  • LRT travel time (-3.2, significant $\sigma$)

• With BE, $\rho$ increases

• Impact of BE
  • Bus: Distance to MRT (2.5)
  • LRT: Distance to MRT of LRT (3.3)
  • Bus: EAI to bus stop (+)
  • Bus: Entropy (-15.4)
  • LRT: Entropy (-44.4, significant $\sigma$ at 0.1)
Findings

• BE factors influencing first-/last-mile travel behaviors
  • Distance to MRT stations
  • Ease of access to buses
  • Land use mix and socioeconomic
• People with greater probability choosing to walk
  • Live or work close to MRT stations
  • Area with high socioeconomic activities and land use mix
• Heterogeneity
  • The impact of physical BE variables (e.g. distance, infrastructures) is relatively homogeneous across the sample.
  • The impact of socioeconomic-related BE (e.g. floor space density, entropy) varies.
Walk-friendly community design

- Active mobility behaviors associate with public health (Celis-Morales et al. 2017, BMJ)
- More compact community with higher floor space density
Deployment of AV

• The Ministry of Transport of Singapore recently made an ambitious plan to deploy autonomous vehicles in 2030

• The findings offer some suggestions for AV deployment and infrastructures installation with consideration of BE.
  • The areas with high first-/last-mile travel demand by bus may also imply high potential demand of AVs in the future.
15% over 15,000 passengers need to take a bus to access to the MRT station from 7 to 9 a.m.

Data source: EZ link data, 2012 Aug.
52% over 15,000 passengers need to take a bus to access to the MRT station from 7 to 9 a.m.

Data source: EZ link data, 2012 Aug.
Thank you!

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