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

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2018/01/10 Lectern Session 744; TRB Paper # 18-02288

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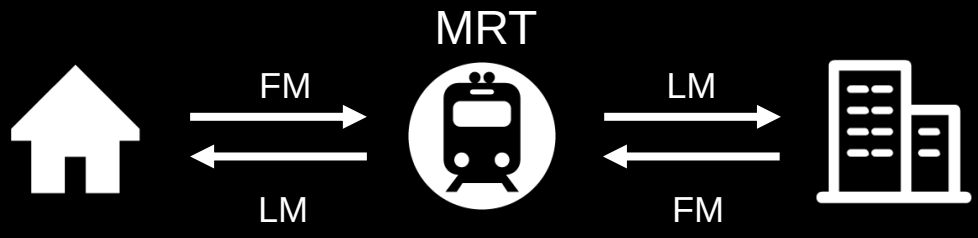
First/Last mile issue in Singapore

- 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:



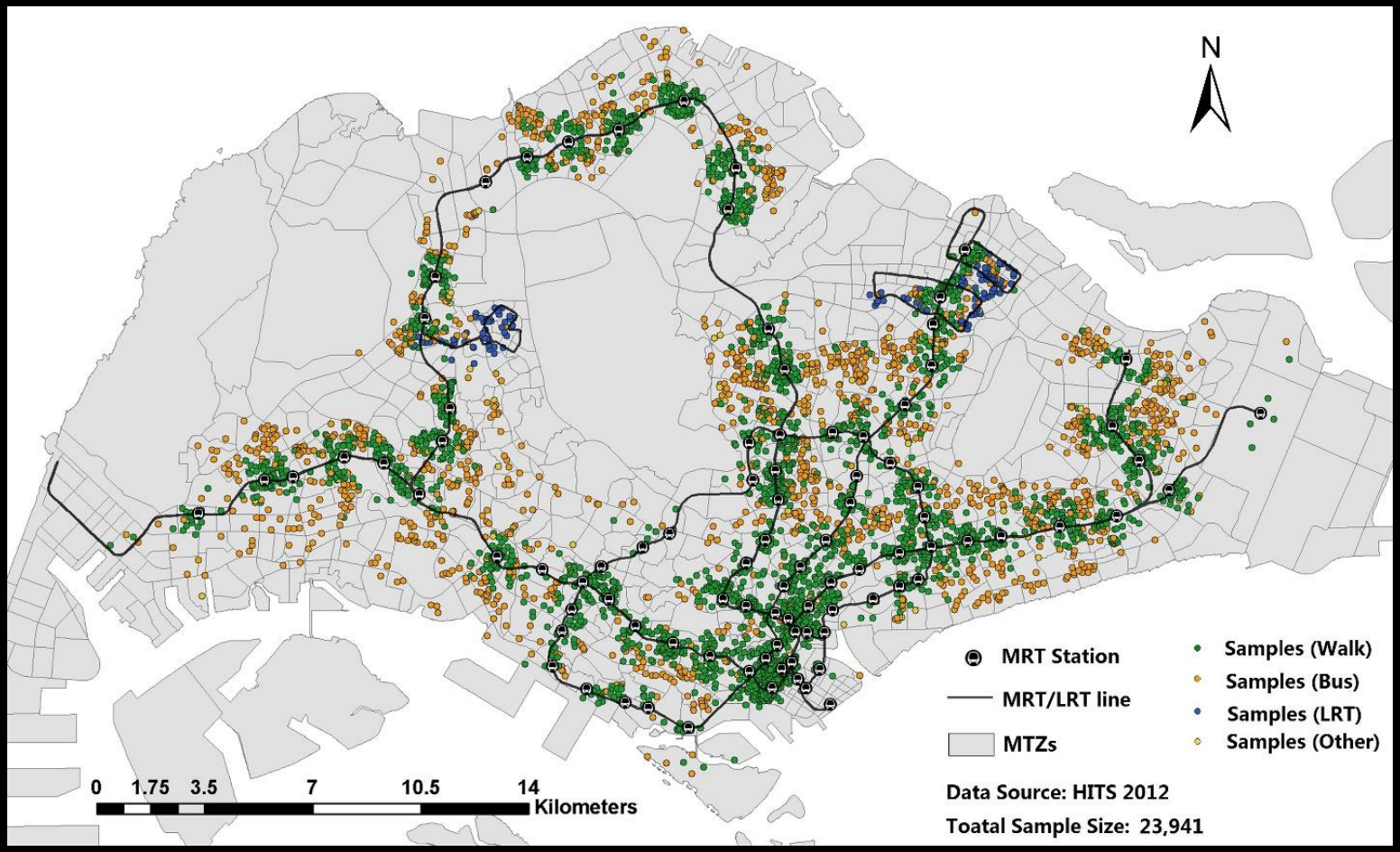
Impact of built environment

- 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

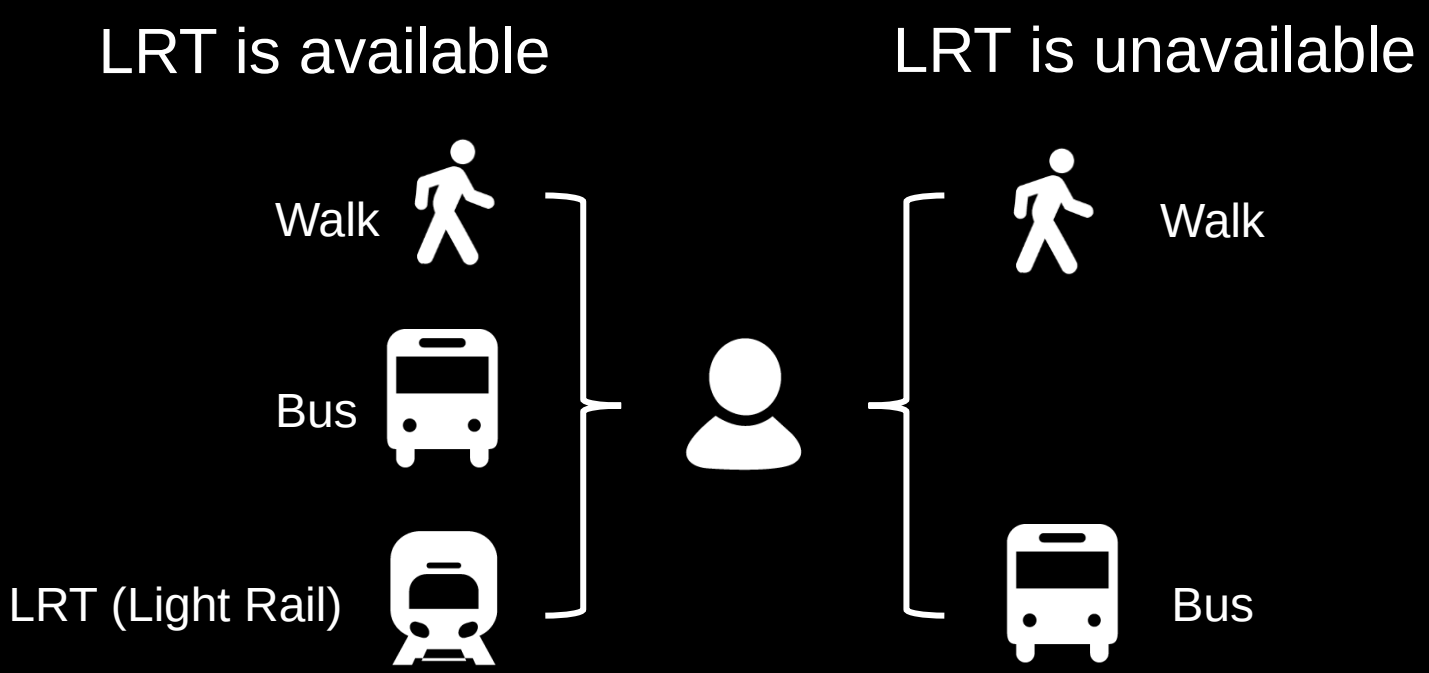
Data

- 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

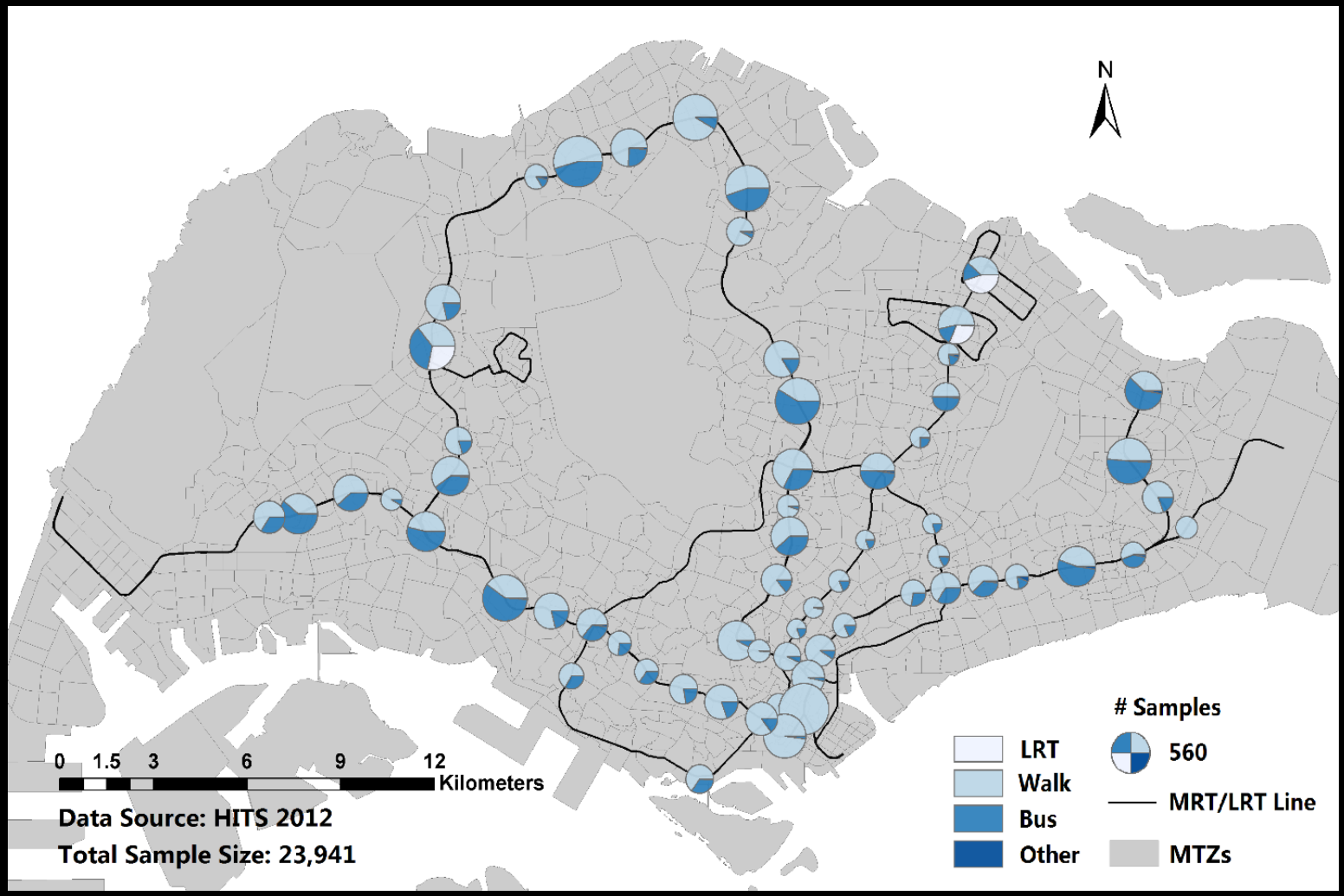
Spatial representativeness of the sample



Mode choice


LRT is available
LRT is unavailable
Walk
Bus
LRT (Light Rail)
Walk
Bus

First & last mile modal share



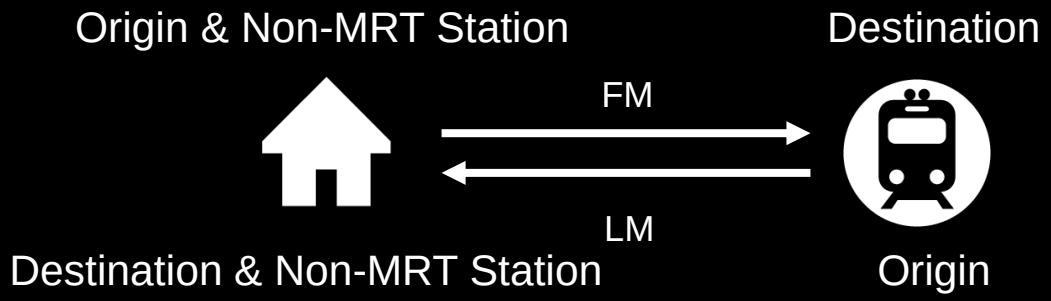
Descriptive Analysis

- 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 α	-	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 α	-	-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 σ)
- 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 σ)
  - Floor space density in non-MRT area (-, significant σ)
  - Road density (+)

Model 2: LRT available

Variable		(a) With BE			(b) Without BE		
		Coefficient	t-test		Coefficient	t-test	
Walk							
Constant α	-	0	fixed		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 α	-	-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	**
Distance to MRT station	†Mean	2.450	3.58	***	-	-	
	‡Std. Dev.	1.430	0.16		-	-	
Entropy (Non -MRT station area)	Mean	-15.40	-2.95	***	-	-	
	Std. Dev.	0.439	0.34		-	-	
EAI to bus stops (Origin)	Mean	3.020	2.76	**	-	-	
	Std. Dev.	0.141	0.19		-	-	
LRT							
Constant α	-	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	
Distance to MRT station	†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							
Observations		2373			2373		
Rho squared		0.891			0.816		
Adjusted Rho squared		0.885			0.813		

Summary of Model 2

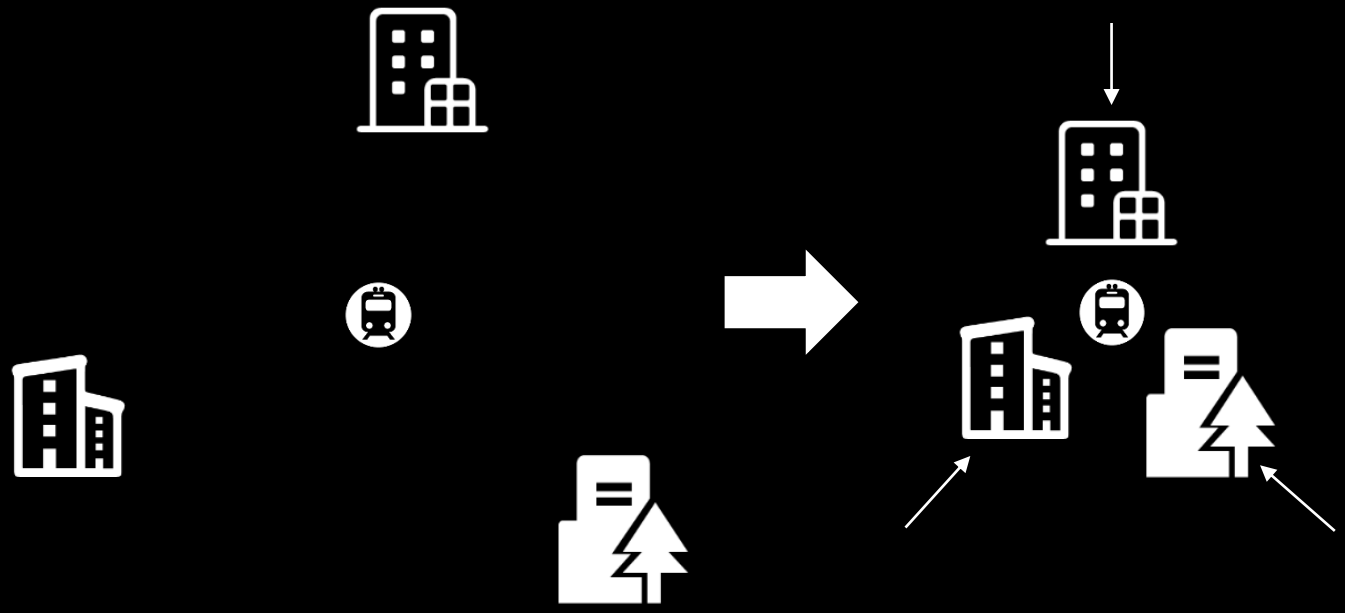
- Trip specific variables
  - Walking time (-0.8, significant σ)
  - Bus travel time (-1.9, significant σ)
  - LRT travel time (-3.2, significant σ)
- With BE, ρ increases
- Impact of BE
  - Bus: Distance to MRT (2.5)
  - LRT: Distance to MRT of LRT (3.3)
  - Bus: EAI to bus stop (+)
  - Bus: Entropy (-15.4)
  - LRT: Entropy (-44.4, significant σ 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

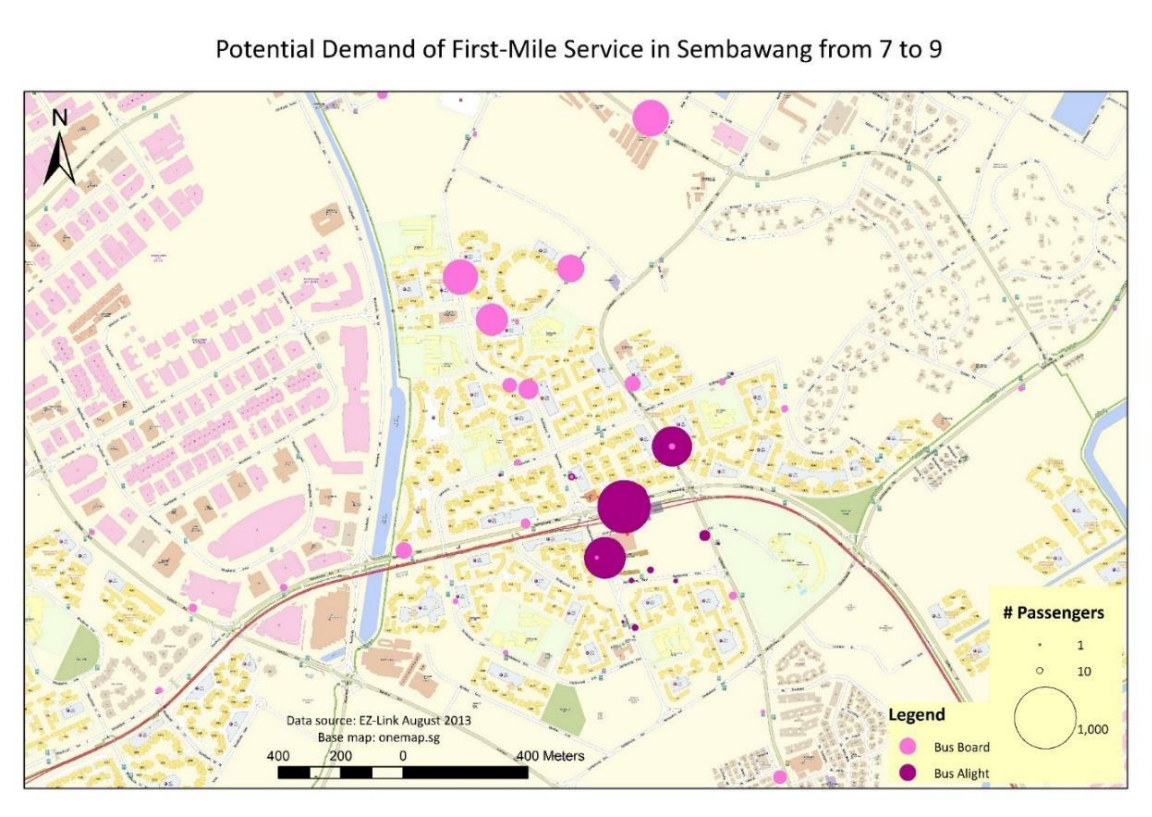
- Active mobility behaviors associate with public health (Celis-Morales et al. 2017, BMJ)
- More compact community with higher floor space density



Deployment of AV

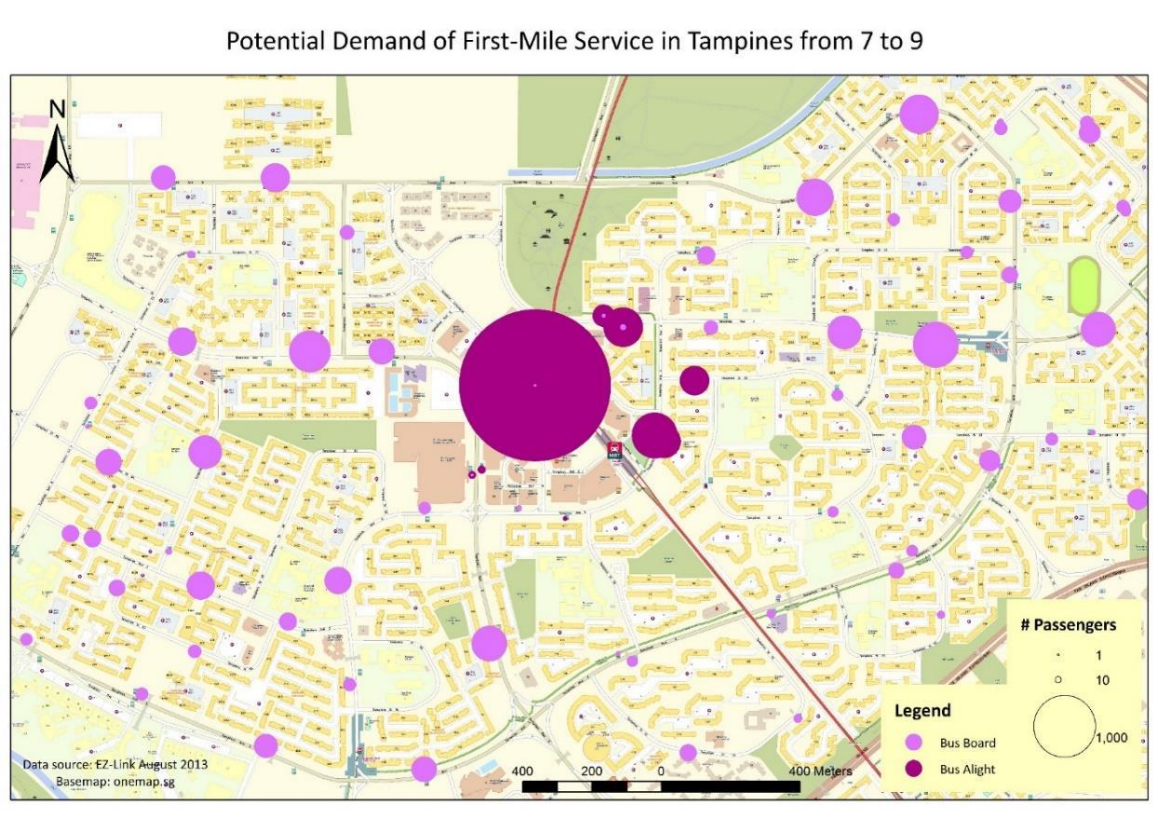
- The Ministry of Transport of Singapore recently made an ambitious plan to deploy autonomous vehicles in 2030
- The findings offer some suggestions for AV deployment and infrastructures installation with consideration of BE.
  - The areas with high first-/last-mile travel demand by bus may also imply 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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