Examining Impacts of Overlapping Bus Services on Dwell Times and Bunching [Paper 20-05679]

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Introduction

This research focuses on the estimation of delays caused by bus interactions at the same stop. Previous research has mostly ignored impact of bus interactions from overlapping service.

This research deviates from previous bus bunching studies by examining interactions between from different routes. Bus bunching is considered, but through the lens of more general interactions.

Research Goals:

- Define and test variables that may explain dwell time increases of interacting buses as bus stops
- Quantify the delays created by each type of these defined interactions using linear and log-linear regression modeling
- Compare results from interaction of overlapping and different service lines to interactions from same bus lines (i.e. bus bunching)

Results may be applied to:

- Improve dwell prediction models
- Analyze the potential impact of route overlaps and bus bunching on dwell times.

Data

This study includes all of the stops in the TriMet system. The data was carefully cleaned for outliers, mistakes, and missing data. Global outliers were identified using the 99.9th percentiles and order statistics were used to define maximum cutoff values for each variables based on the calculated distributions of their maximums. The final data sets included:

- 6,614 unique stops
- 86 different routes
- 272 weekdays between mid-September 2017 and the end of November 2018
- 35,277,002 data points

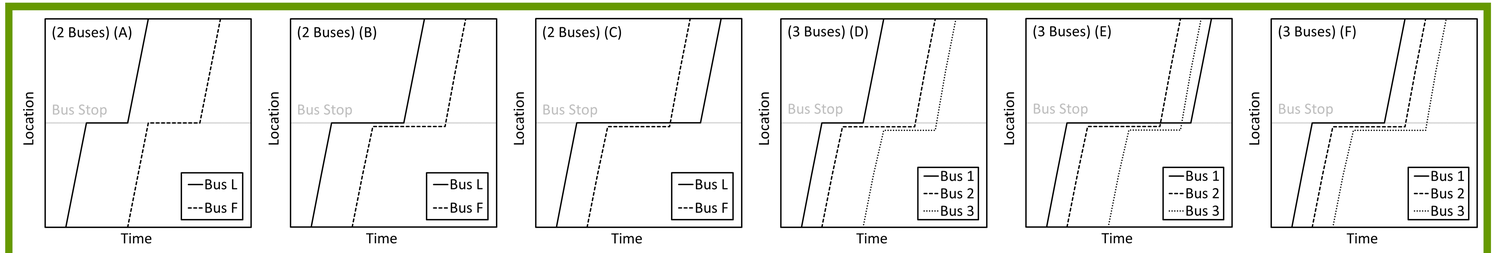

FIGURE 1 — Time-space diagrams for scenarios of bus interactions at a single bus stop for bus L (Leader) and bus F (Follower) (A–C) and Time-space diagrams for sample scenarios of bus interactions at a single bus stop for three interacting buses (D–F)

	Order of Events				Applicable Interaction Variables	
Scenario	1st	2nd	3rd	4th	Bus L (Leader)	Bus F (Follower)
(A)	Bus L Arrives	Bus L Leaves	Bus F Arrives	Bus F Leaves	None	None
(B)	Bus L Arrives	Bus F Arrives	Bus L Leaves	Bus F Leaves	Leader	Follower
(C)	Bus L Arrives	Bus F Arrives	Bus F Leaves	Bus L Leaves	Overtaken	Jumping

TABLE 1 — Order of events for scenarios (A–C) of bus interactions and applicable interaction variables

Scenario	Bus 1	Bus 2	Bus 3
(E)	Leader=1	Leader=1	Follower=1
		Follower=1	
(F)	Leader=2	Leader=1	Follower=2
		Follower=1	
(G)	Overtaken=2	Leader=1	Follower=1
		Jumping=1	Jumping=1

TABLE 2 — Interaction variables for 3-bus examples of scenarios (D–F) in FIGURE 1

Interaction Variables

- *Leader* – applies to Bus L only in Scenario (B)
- *Follower* – applies to Bus F only in Scenario (B)
- *Overtaken* – applies to Bus L only in Scenarios (C)
- *Jumping* – applies to Bus F only in Scenarios (C)

Bunching Variables

When Buses are from the same route…

- *Bunching_L* – applies to Leader
- *Bunching_F* – applies to Follower
- *Bunching_O* – applies to Overtaken bus
- *Bunching_J* – applies to Jumping bus

Base Model *Independent* Variables

- ***Ons:*** Number of passengers boarding a bus at a specific stop (passengers board only from front door)
- ***Offs:*** Number of passengers alighting a bus at a specific stop (passengers alight from both doors)
- ***Ons^2:*** Square of number of boarding passengers
- ***Offs^2:*** Square of Number of alighting passengers
- ***Lift: Binary*** — 1 if wheelchair lift is used
- ***Mall: Binary*** — 1 if stop is located on Downtown Transit Corridor of Portland
- ***Avg. Speed (mph):*** Average speed of bus in the segments immediately preceding and a bus stop
- ***Early*Timepoint (min):*** Minutes ahead of schedule at timepoints stops
- ***Traffic Signal: Binary*** — 1 if bus stop is located near a signalized intersection

Model *Dependent* Variables

- ***Dwell:*** Door Open time when a bus is serving passengers at a bus stop.
- ***ln*(Dwell):** Natural Logarithm of *Dwell*.
  Note: Improves normality of modeling

	Estimate		t-value	
Variables	Dwell	*ln*(Dwell)	Dwell	*ln*(Dwell)
(Intercept)	8.30	1.911	288	1343
Ons	3.81	0.323	366	629
Offs	1.83	0.160	201	357
Ons^2	-0.05	-0.018	-32	-238
Offs^2	-0.05	-0.007	-50	-138
Lift	37.29	1.273	580	400
Mall	2.51	0.123	62	62
Avg. Speed (mph)	-0.10	-0.006	-85	-100
Early*Timepoint (Min)	2.34	0.100	54	48
Traffic Signal	0.64	0.053	42	70
Leader_I1	3.10	0.143	41	39
Follower_I1	3.35	0.200	45	54
Overtaken_I1	11.44	0.396	60	42
Leader_I2	6.47	0.155	17	8
Follower_I2	8.27	0.343	22	19
Overtaken_I2	26.56	0.848	17	11
Adj. R-Squared	0.3541	0.4060		
Num. Obs.	2,113,386	2,116,533		

TABLE 3 — Linear and Log-Linear interaction model for first and second order interactions and all other buses

Model Notes: Multiple models were tested for each new variable. The magnitude of coefficients, their signs and significance were consistent across all models and different data sets.

Conclusions

- *Interactions:*
  - Increase the expected dwell times
  - Increase the expected number of passenger movements
- *Type of interaction:*
  - Changes the expected increase in dwell times
  - Changes the expected number of passenger movements
- *Number of interactions:*
  - Increases the expected increase to dwell time per interaction
- *Overlapping routes:*
  - Create increase variability in dwell time
  - Contribute significantly to bus bunching

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