Dwell Time Models

Outline

1. Dwell Time Theory
2. Bus Dwell Time Model[1]
3. Light Rail Dwell Time Model[2]
4. Heavy Rail Dwell Time Model[3]

1 Milkovits, M.N., “Modeling the Factors Affecting Bus Stop Dwell Time: Use of Automatic Passenger Counting, Automatic Fare Counting, and Automatic Vehicle Location Data." Transportation Research Record: Journal of the Transportation Research Board, pp pp 125-130 (2008).

2 Wilson, N.H.M. and T. Lin, "Dwell-Time Relationships for Light Rail Systems," *Transportation Research Record #1361*, 1993, pp. 296-304.

3 Puong, A., "Dwell Time Model and Analysis for the MBTA Red Line." Internal memo, MIT, March 2000.

Dwell Time Theory

- **Vehicle dwell time affects:**
  - **system performance**
  - **service quality**
- **A critical element in vehicle bunching resulting in:**
  - **high headway variability**
  - **high passenger waiting times**
  - **uneven passenger loads**
- **Dwell time impact on performance depends on:**
  - **stop/station spacing**
  - **mean dwell as proportion of trip time**
  - **mean headway**
  - **operations control procedures**

EXAMPLES:

Commuter rail ---> little impact of dwell time on performance

Long, high-frequency bus route ---> major impact

Dwell Time Theory

- **Dwell time depends on many factors:**
  - **Human, modal, operating policies & practices, mobility, weather, etc.**
- **For a given system we have the following possible models:**

1. **Single door, no congestion and interference:**

   DOT = a + b(DONS) + c(DOFFS)

2. **Single door with congestion and interference:**

   DOT = a + b(DONS) + c(DOFFS) + d(DONS+DOFFS)(DTD)

Dwell Time Theory (cont'd)

- **For a given system we have the following possible models ...**

3. Single car with m doors:

$DT = \max(DOT_1 \ldots, DOT_m)$

With balanced flows:

DT = a + b/m(CONS) + c/m(COFFS) + d/m(CONS+COFFS)(STD)

4. *n*-car train:

$DT = \max(DT_1, \ldots, DT_n)$

With balanced flows:

DT = a + b/nm(TONS) + c/nm(TOFFS) + d/nm(TONS+TOFFS)(STD)

Bus Dwell Time: Prior Work

Manually collected data

- Limited data on infrequent events
  - Crowding
- Do not include latest fare media

Automatically collected data

- Does not include fare media information
- Poor fit of model

Transit Capacity and Quality of Service Manual

- Assumes a half-second penalty per passenger for crowding

Ref: Milkovits (2008)

Objective

- **Develop a dwell time model using automatically collected data**
- **Dwell time factors:**
  - **Boarding and alighting passengers**
  - **Onboard passengers**
  - **Fare media type**
  - **Alighting door selection**
  - **Bus type**
- **Minimize the unexplained variation in dwell time**
- **Evaluate impact on dwell time of:**
  - **fare media type**
  - **bus design**
  - **enforcement of rear-only alightings**

Ref: Milkovits (2008)

Data Set

- Automatically collected data from Chicago Transit Authority bus network
- Non-Timepoint, Far-Side, Known Stops
- Functioning APC counters on all doors
  - Verified by non-zero counts across day
  - Minimum per-passenger dwell time of .5 seconds
- Link-in AFC transactions
  - Fare transactions that take place within the dwell time
- Data from entire month of November 2006
  - 173,750 Records
  - 2,977 Operators
  - 85 Routes
  - 927 Stops

Ref: Milkovits (2008)

Model Formulation

- **Predict dominant door activity**
- **Segment data and compare by:**
  - **Bus type**
  - **Crowding (passengers > number of seats)**
- **Combine the data and test for significant differences in the estimators**

Ref: Milkovits (2008)

Dwell Time Estimates – Front Door

Variable	DUMMY	est	t-stat	Adjusted R^2: 0.73 Passenger Levels
intercept		-1.22	-26.49	All
NABI		0.53	7.81	
FON_EX		3.68	154.17	
	NOVA	0.38	10.51	
	NABI	-0.59	-11.32	
FOFF3UP		1.52	26.22	
CARDS		2.62	10.15	Open
TICKET		4.88	39.55	
	NFLYER	-0.58	-3.62	
FOFF12		2.83	104.59	
F_SENSOR		4.60	21.55	
AFC_TRANS		4.35	15.54	Crowded
FOFF12		3.52	22.54	
	NFLYER	-0.74	-3.71	
ST2_PASS		0.0011	5.56	
	NFLYER	0.0017	3.53	

Ref: Milkovits (2008)

Dwell Time Estimates – Rear Door

				Adjusted R^2: 0.37
Variable	**DUMMY**	**est**	**t-stat**	**Passenger Levels**
Intercept		1.42	22.49	All
	NABI	2.64	21.26	
ROFF		1.69	40.86	
	NOVA	0.42	7.47	
	NABI	-0.42	-5.37	
ST2_PASS		0.005	5.64	Crowded
	NOVA	0.004	2.11	
	NABI	-0.003	-3.36	

Ref: Milkovits (2008)

Bus Dwell Time Model: Key Findings

- **Smart media loses benefit in crowded conditions**
  - **Drops from 2 second advantage in non-crowded conditions**
- **Crowding impact increases exponentially**
- **Bus attributes impact dwell time**
  - **Location of magnetic stripe reader (half second difference)**
  - **Double-wide doors**
- **Front door alightings may affect dwell time, while rear door alightings will happen in parallel**

Ref: Milkovits (2008)

MBTA Green Line Analysis

- Branching network of 28 miles (45 km) and 70 stations
- 52-seat ALRVs operate in 1-, 2-, and 3-car trains
  - high floor, low platform configuration
  - 3 doors per car on each side
  - single side boarding/alighting
- Trunk service in central subway:
  - 10 or 14 stations on round-trip
  - 1- to 2-minute headways
  - peak flows ≈10,000 passengers/hour

Ref: Wilson and Lin (1993)

Models with Crowding Term

A. One-car trains:

DT = 12.50 + 0.55*TONS + 0.23*TOFFS + 0.0078*SUMASLS
(8.94) (3.76) (2.03) (6.70)

SUMASLS = TOFFS*AS + TONS*LS

(R^2 = 0.62)

B. Two-car trains:

DT = 13.93 + 0.27*TONS + 0.36*TOFFS + 0.0008*SUMASLS
(7.43) (2.92) (3.79) (2.03)

(R^2 = 0.70)

Ref: Wilson and Lin (1993)

Predicted Dwell Times

ONS	LPL	1-Car DT	2-Car DT
0	any #	12.5	13.9
10	< 53	20.3	20.2
10	150	35.6	21.0
20	< 53	28.1	26.5
20	150	58.7	28.1
30	< 53	35.9	32.8
30	150	81.8	35.1

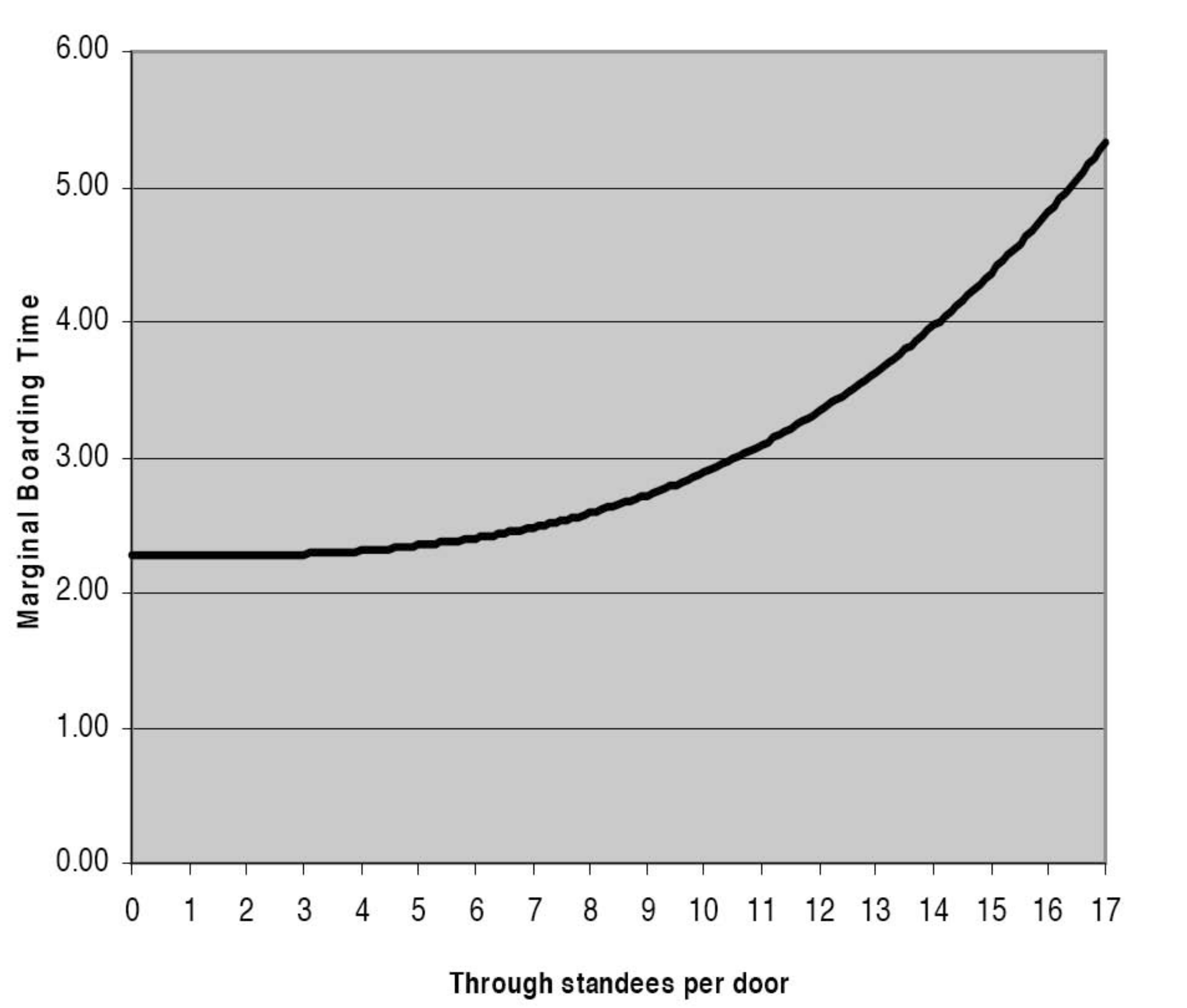
Ref: Wilson and Lin (1993)

Findings

- **Dwell times for ALRVs are quite sensitive to:**
  - **Passenger flows**
  - **Passenger loads**
- **The crowding effect may well be non-linear.**
- **Dwell times for multi-car trains are different form those for one-car trains.**
- **The dwell time functions suggest high sensitivity of performance to perturbations**
- **Effective real-time operations control essential**
- **Running mixed train lengths dangerous**
- **Simulation models of high frequency, high ridership light rail lines need to include realistic dwell time functions.**

Ref: Wilson and Lin (1993)

Heavy Rail Marginal Boarding Time



Ref: Puong (2000)

Heavy Rail Dwell Time Function

$$DT = 12.22 \quad +2.27 \cdot B_d \quad +1.82 \cdot A_d \quad +6.2\,10^{-4} \cdot TS_d^3 B_d \quad (\bar{R}^2 = 0.89) \quad (9)$$

$$(12.82) \quad (7.11) \quad (9.07) \quad (4.70)$$

where

A_d = alighting passengers *per door*,
B_d = boarding passengers *per door*, and
TS_d = through standees per door,
i.e., total through standees divided by the number of doors

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Ref: Puong (2000)

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