Quantifying the Impact of Real-Time Information on Transit Ridership

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Outline

- Motivation
- Research Approach
- Results
  - New York City, NY
  - Tampa, FL
  - Atlanta, GA
- Comparison & Conclusions

Motivation

- Public transit can be unreliable.
- Improving reliability can be expensive.
- Providing real-time transit information to riders via personal devices can help.

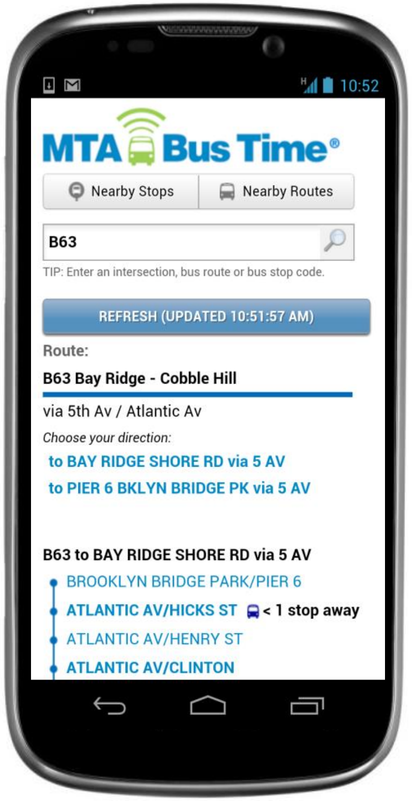


Image: NYC Bus Time Mobile Website

Key Prior on the Impacts of Real-Time Information

Decreased Wait Times

- Watkins et al. (2011)
- Location: Seattle
- Conclusion: Both actual wait times and perceived wait times of real-time bus information users were less than non-users

could lead to

Increased Satisfaction

- Zhang, Shen, Clifton (2008)
- Location: Maryland
- Conclusion: Overall satisfaction with transit service increased due to real-time shuttle bus information

could lead to

Increased Ridership

- Tang & Thakuriah (2012)
- Location: Chicago
- Conclusion: Modest increase in ridership (126 rides/route on average weekday) attributable to real-time bus information

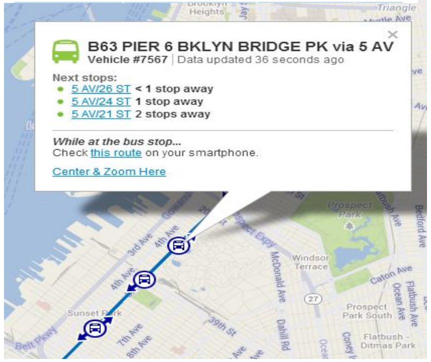
1. Watkins, K. E., Ferris, B., Borning, A., Rutherford, G. S., & Layton, D. (2011). Where Is My Bus? Impact of mobile real-time information on the perceived and actual wait time of transit riders.
2. Zhang, F., Shen, Q., & Clifton, K. J. (2008). Examination of Traveler Responses to Real-Time Information About Bus Arrivals Using Panel Data. Transportation Research Record. 2082, 107–115.
3. Tang, L., & Thakuriah, P. (Vonu). (2012). Ridership effects of real-time bus information system: A case study in the City of Chicago. Transportation Research Part C: Emerging Technologies, 22, 146–161.

Research Approach: OneBusAway

- Evaluation of real-time information focusing on OneBusAway, which is an open source system that relies on open data
- Where is OneBusAway used?
  - Seattle, WA
  - New York, NY
  - Tampa, FL
  - Atlanta, GA
  - Others
- See http://onebusaway.org/

OneBusAway

MTA Bus Time®



Study Locations

	New York City	Tampa	Atlanta
Transit Agency	New York City Transit	HART	marta
Size of Ridership (Annual Unlinked Bus Trips)*	Large (805,381,461)	Small (14,314,610)	Medium (61,596,727)
Real-Time Information Deployment	Bus Time deployed on groups of routes between 2011 and 2014	OneBusAway spring 2013 (pilot); OneBusAway full deployment in summer 2013	OneBusAway spring 2013 (beta); MARTA apps in fall 2013; OneBusAway full deployment in February 2014
Primary Data Sources	Route-level ridership counts	Web-based surveys	Web-based survey combined with smart card data
Methodology	Natural experiment with panel regression	Behavioral experiment with a before-after control group design	Before-after analysis of transit trips

* Unlinked bus trips are 2012 Statistics from the National Transit Database

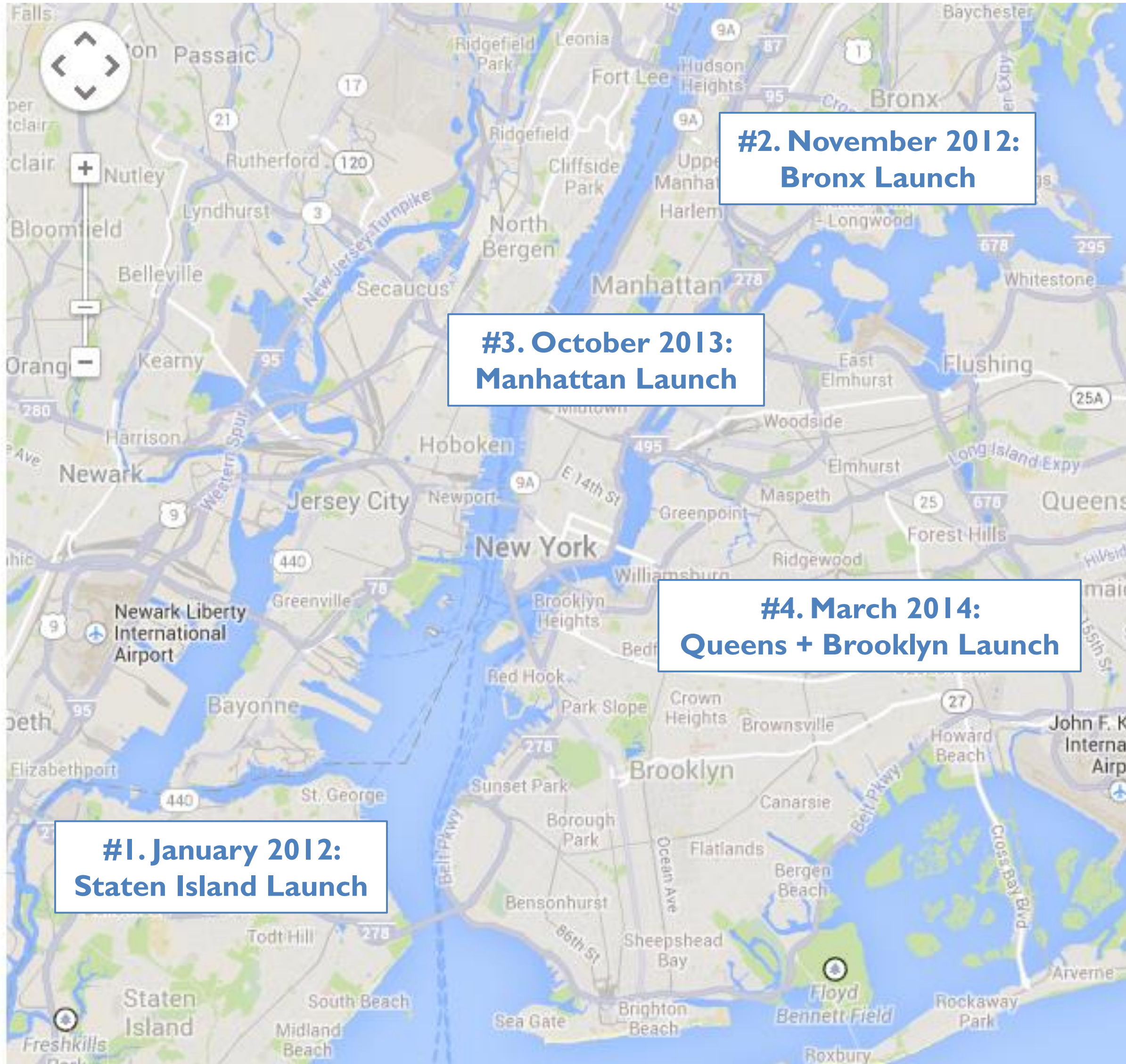
STUDY 1: NEW YORK CITY

Full Manuscript: Brakewood, Candace, Gregory Macfarlane, and Kari Watkins (2015). *The Impact of Real-Time Information on Bus Ridership in New York City.* Transportation Research Part C: Emerging Technologies, Volume 53, pp. 59-75

Roll-out of Bus Time in New York City

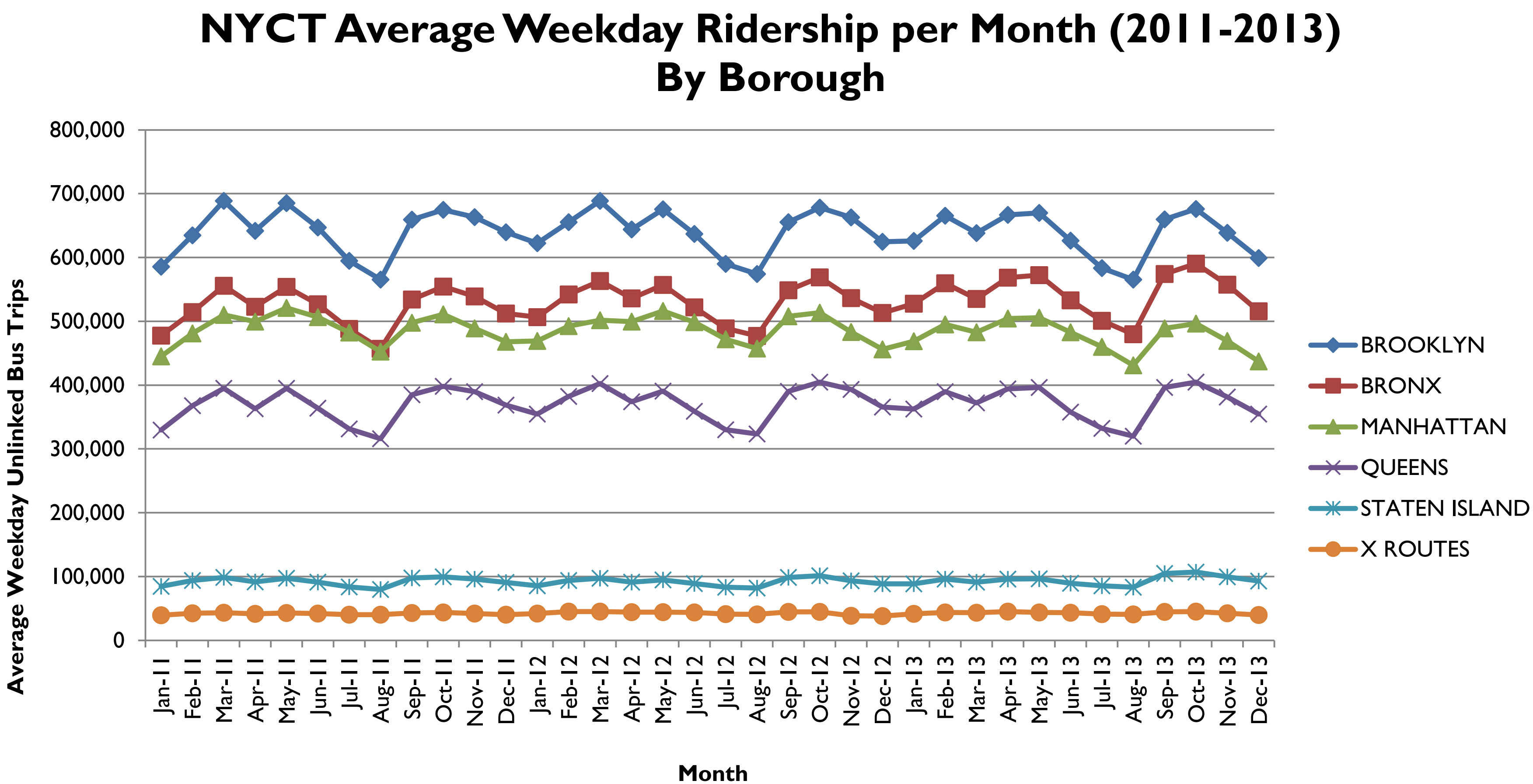
Bus Time modeled with the following dates:

- Feb 2011: B63
- Jan 2012: All Staten Island Routes
- Apr 2012: M34
- Jul 2012: B61
- Nov 2012: All Bronx Routes; M100
- Oct 2013: All Manhattan Routes



Route-level Ridership

The dependent variable of interest is monthly route-level ridership over a 3 year panel (t=36 months). All NYCT operated routes were included in the analysis (i=185* routes).



* Ridership statistics for a small number of NYCT routes were combined due to joint scheduling/counts (e.g. M101/2/3, BX40/42, etc.)

Data Sources & Variables

Many factors affect transit ridership, including transit-related variables (e.g., fares) and external factors (e.g., weather). The following variables were considered in the analysis.

	Variable Description (Units)	Geographic Unit	Variable Type	Data Source
Dependent Variable	Average Weekday Unlinked Bus Trips	Route-level	Continuous	New York City Transit
Explanatory Variables (Transit-related)	Bus Time Real-Time Information Available	Route-level	Binary	MTA Press Releases
	Bus Average Weekday Scheduled Revenue Miles	Route-level	Continuous	New York City Transit
	Bus and Rail Base Fare ($)	City-wide	Continuous	MTA Press Releases
	Rail Actual Vehicle Revenue Miles	City-wide	Continuous	New York City Transit
	Rail Scheduled Vehicles Operating in Maximum Service	City-wide	Continuous	New York City Transit
Explanatory Variables (External Factors)	Bike-sharing	Borough-level	Binary	Citibike
	Population (only annual estimates available; linear interpolation per month)	Borough-level	Continuous	US Census Bureau
	Gas Price ($/gallon)	City-wide	Continuous	US Energy Information Administration
	Unemployment Rate (percent)	City-wide	Continuous	US Bureau of Labor Statistics
	Weather (Average temperature, snowfall, precipitation; measurement at Central Park)	City-wide	Binary (Temperature); Continuous (Snow/rain)	National Oceanic & Atmospheric Administration
	Hurricane Sandy	City-wide	Binary	NYU Rudin Center Report

Methodology: Panel Regression

- OLS* regression is insufficient: $y_{it} = \alpha + \beta x_{it} + \varepsilon_{it}$

  where

  y = ridership

  i = bus route

  t = month

  x = explanatory variables

  $u_i + \varepsilon_{it}$

- Two types of panel regression were evaluated
  - Random Effects: $y_{it} = \alpha_i + \beta x_{it} + \varepsilon_{it}$
  - Fixed Effects: $y_{it} - \overline{y}_i = \beta(x_{it} - \overline{x}_i) + \varepsilon_{it}$

- Fixed Effects panel regression was selected

*Ordinary least squares

Model 1: Fixed Effects Regression
Single Bus Time Variable

Variable	Estimate	Robust Standard Error
Bus Service by Borough (Revenue Miles)		
Brooklyn	5.381	(0.693)***
Bronx	5.073	(0.935)***
Manhattan	3.051	(1.227)**
Queens	2.765	(1.275)**
Staten Island	0.212	(0.301)
Other Transit-Related Variables		
Select Bus Service	-262.039	(461.757)
Fare ($)	-862.884	(121.641)***
Rail Revenue Miles (thousands)	0.072	(0.008)***
Rail Vehicles in Max. Service	-2.566	(0.398)***
Other External Factors		
Citi Bike in Manhattan	-556.237	(143.921)***
Citi Bike in Brooklyn	-375.308	(96.701)***
Unemployment Rate	-243.379	(40.208)***
Cold Month	-249.223	(30.778)***
Hot Month	-246.906	(35.622)***
Total Monthly Snowfall (mm)	-0.819	(0.070)***
Total Monthly Precipitation (mm)	-0.366	(0.060)***
Hurricane Sandy	206.319	(51.793)***
Real-Time Information	**118.278**	**(52.695)****
Monthly Dummy Variables (see paper)		
R^2	0.47	

Significance codes: p<0.1; ** p<0.05; *** p<0.01
Balanced Panel: routes=185; time periods=36; N=6660
Huber-White Robust SE

Interpretation

- Bus service increases → bus ridership increases
- Availability of bike-sharing → bus ridership decreased
- Hurricane Sandy → bus ridership increased
- **Bus Time real-time information → increased route-level ridership ~118 rides per route per weekday (median of 1.7%),**

Model 2: Fixed Effects Regression with Real-Time Information by Route Size

Variable	Estimate	Robust Standard Error
Bus Service by Borough (Revenue Miles)		
Brooklyn	5.376	(0.693)***
Bronx	5.017	(0.945)***
Manhattan	3.153	(1.229)**
Queens	2.762	(1.274)**
Staten Island	0.03	(0.329)
Other Transit-Related Variables		
Select Bus Service	-326.825	(458.593)
Fare ($)	-868.031	(123.463)***
Rail Revenue Miles (thousands)	0.073	(0.008)***
Rail Vehicles in Maximum Service	-2.564	(0.393)***
Other External Factors		
Citi Bike in Manhattan	-535.102	(152.800)***
Citi Bike in Brooklyn	-375.586	(96.759)***
Unemployment Rate	-244.935	(40.397)***
Cold Month	-247.74	(30.635)***
Hot Month	-245.322	(35.529)***
Total Monthly Snowfall (mm)	-0.82	(0.070)***
Total Monthly Precipitation (mm)	-0.366	(0.061)***
Hurricane Sandy	204.454	(51.790)***
Real-Time Information		
Small Routes (Q1)	**16.256**	**(62.551)**
Smaller Medium Routes (Q2)	**147.101**	**(106.412)**
Larger Medium Routes (Q3)	**-35.114**	**(106.778)**
Large Routes (Q4)	**340.466**	**(124.803)*** **
Monthly Dummy Variables (see paper)		
R^2	0.47	

Significance codes: p<0.1; ** p<0.05; *** p<0.01
Balanced Panel: routes=185; time periods=36; N=6660
Huber-White Robust SE

Interpretation

- Bus service increases → bus ridership increases
- Availability of bike-sharing → bus ridership decreased
- Hurricane Sandy → bus ridership increased
- **Bus Time on Large Routes→ increased ridership by ~340 rides per weekday on the largest quartile of routes (median of 2.3%)**

New York City Conclusions

- **Conclusions**
  - Model 1: Average increase of ~118 trips per route per weekday (median of 1.7%), which is similar to Chicago
  - Model 2: Average increase of ~340 trips per weekday on the largest quartile of routes (median of 2.3%)
  - Weekday farebox revenue from these additional trips was also investigated ($5.6-$6.3 million over three years).

- **Limitations**
  - Short Timescale: Study period had only 3 months of Bus Time in Manhattan and was prior to the Brooklyn and Queens launch
  - Unit of Analysis: Only considered weekday trips (not weekend)

STUDY II: TAMPA

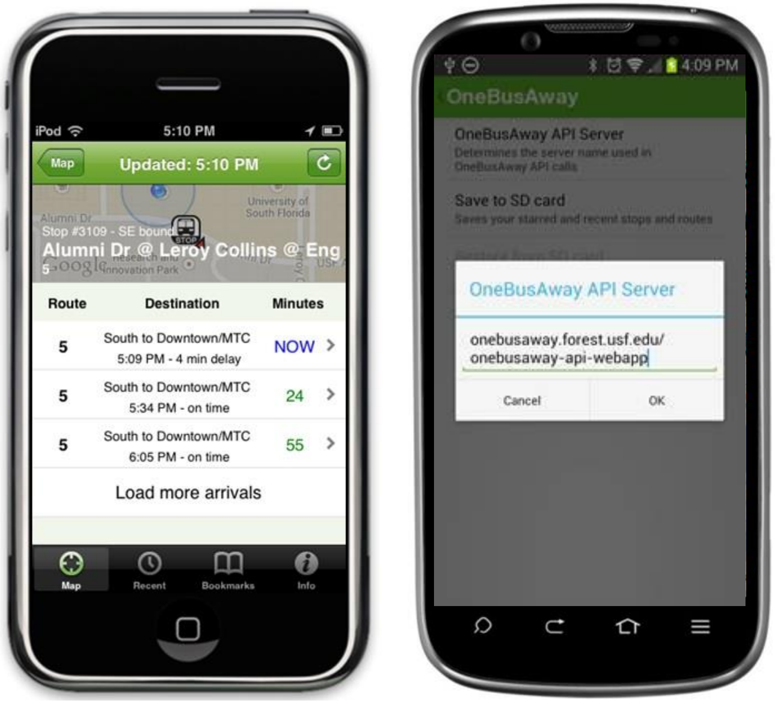
Full Manuscript: Brakewood, Candace, Sean Barbeau, and Kari Watkins (2014). *An Experiment Evaluating the Impacts of Real-Time Transit Information on Bus Riders in Tampa, Florida*. Transportation Research Part A: Policy and Practice, Volume 69, pp. 409-422.

Methodology

Before-After Control Group Research Design

- **Motivation:** HART provided USF & Georgia Tech special access to real-time data
- **Recruitment:** HART website/email list (Incentive of 1 day bus pass)
- **Measurement:** Web-based surveys
- **Group Assignment:** Random number generator
- **Treatment:** 5 interfaces of OneBusAway (3 websites & 2 smartphone apps)

Limiting the Treatment: iPhone & Android Apps

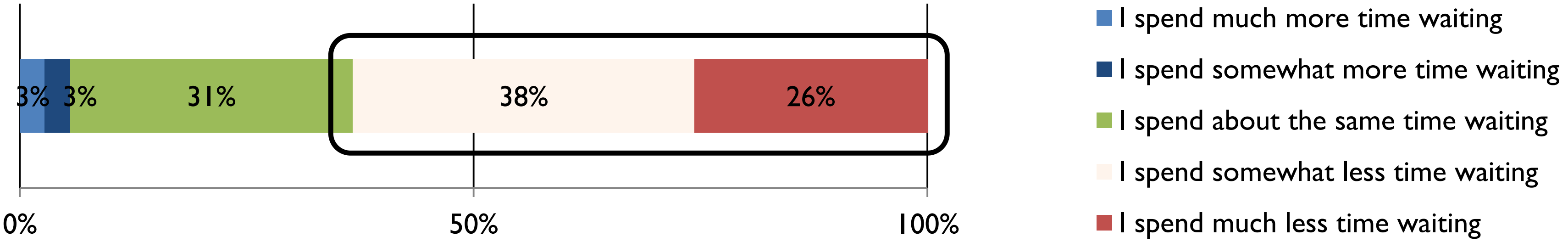


Analysis of Usual Wait Times

- Identical questions about usual wait time on regular route on the before and after surveys

Usual Wait Time (minutes)	**Sample Size** n	**Before** Mean (SD)	**After** Mean (SD)	**Difference** Mean
Control Group	102	10.71 (3.88)	10.50 (4.25)	-0.21
Experimental Group	107	11.36 (4.06)	9.56 (4.68)	-1.79
Comparison	*Difference of Means: t=2.65, two-tailed p=0.009 < 0.01*			

- Experimental group post-wave survey only: *Has using OneBusAway changed the amount of time you wait at the bus stop?*



Bottom graphic: n=109.
Figures rounded to the nearest whole percent.

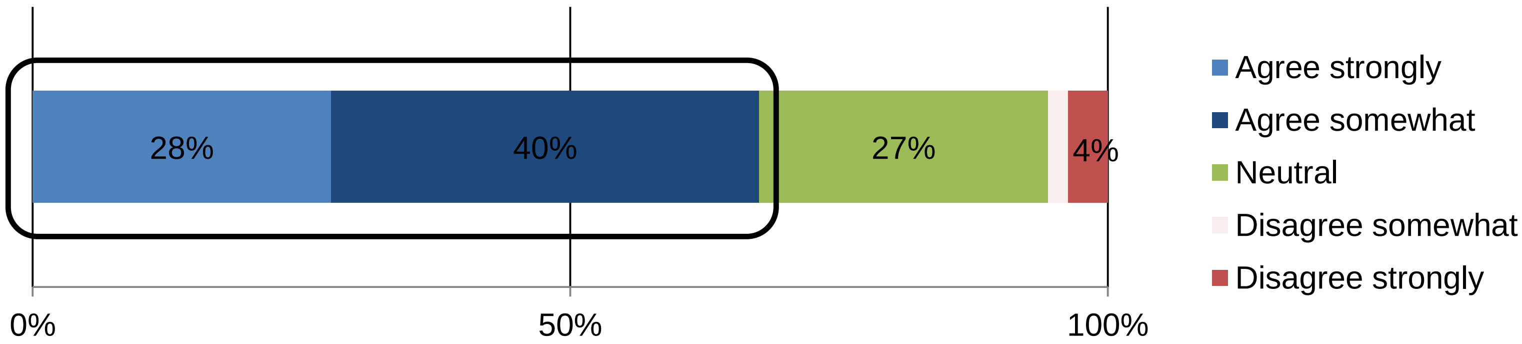
Analysis of Feelings While Waiting for the Bus

- Identical questions about feelings while waiting asked on the before and after surveys

	Control Group % Frequently + Always		Experimental Group % Frequently + Always		Diff. in Gain Scores Wilcoxon Test		
Feelings	Before	After	Before	After	W	p-value	
Productive	11%	10%	10%	17%	6201	0.051	*
Anxious	18%	19%	26%	25%	4548	0.082	*
Relaxed	34%	34%	27%	25%	5518	0.592	
Frustrated	24%	26%	25%	18%	4241	0.006	***

*Significance: * p<0.10; ** p<0.05; *** p<0.01*

- Experimental group post-wave survey only asked: *Since you began using OneBusAway, do you feel more relaxed when waiting for the bus?*



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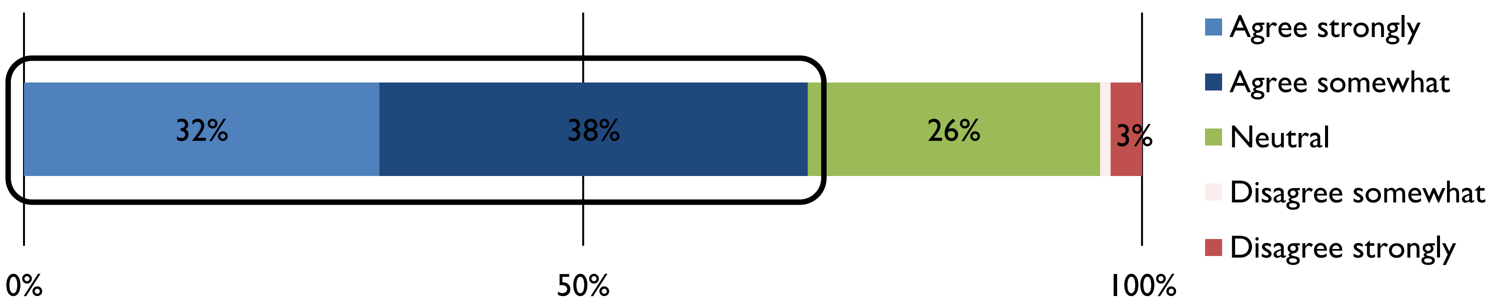
Analysis of Satisfaction

- Identical questions about satisfaction asked on the before and after surveys

	Control Group % Satisfied		Experimental Group % Satisfied		Diff. in Gain Scores Wilcoxon Test		
	Before	After	Before	After	W	p-value	
How frequently the bus comes	37%	41%	40%	44%	5812	0.459	
How long you have to wait for the bus	39%	34%	36%	46%	6425	0.020	**
How often the bus arrives at the stop on time	54%	45%	45%	59%	7094	0.0001	***
How often you arrive at your destination on time	57%	53%	55%	63%	5835	0.236	
How often you have to transfer buses to get to your final destination	44%	42%	38%	36%	4916	0.342	
Overall HART bus service	63%	59%	57%	58%	5717	0.410	

*Significance: * p<0.10; ** p<0.05; *** p<0.01*

- Experimental group post-wave survey only asked: *Since you began using OneBusAway, do you feel more satisfied riding HART buses?*



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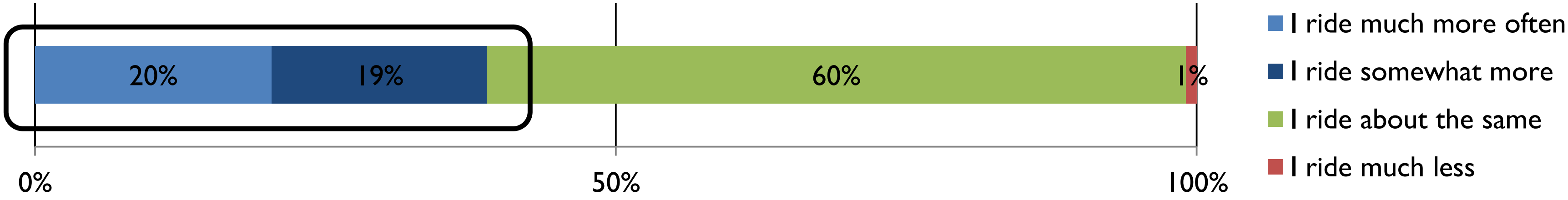
Figures rounded to the nearest whole percent.

Analysis of Bus Trips/Week

- Identical questions about the number of HART bus trips/week on the before and after surveys

Trips/Week	Sample Size n	Before Mean (SD)	After Mean (SD)	Difference Mean
Control Group	107	7.03 (3.79)	6.63 (4.09)	-0.40
Experimental Group	110	7.09 (3.94)	6.40 (3.71)	-0.69
Comparison	*Difference of Means: t=0.66, two-tailed p=0.512*			

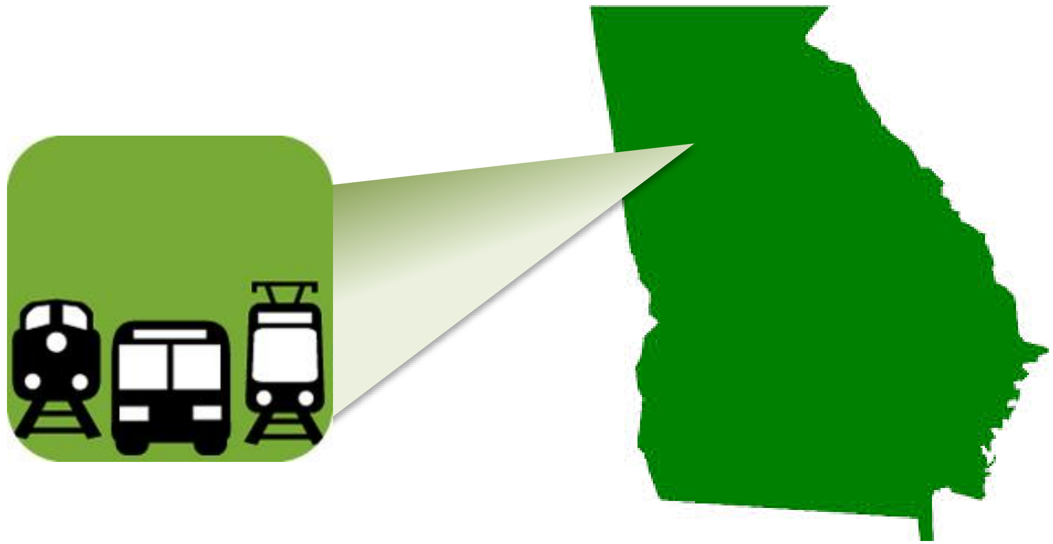
- Experimental group post-wave survey only: *Has using OneBusAway changed the number of HART bus trips that you take?*



Bottom graphic: n=108.
0% selected "I ride somewhat less."
Figures rounded to the nearest whole percent.

Tampa Conclusions

- Significant improvements in the "waiting experience"
  - Decreases in self-reported usual wait times
  - Decreases in negative feelings, particularly frustration
  - Increases in satisfaction with wait times
- Little evidence supporting a change in transit trips
  - Approx. 1/3 of RTI users stated they ride the bus more frequently, perhaps because of:
    - Affirmation bias of respondents
    - Scale of measurement (trips per week)
  - Only riders within sphere of transit agency



STUDY III: ATLANTA

In preparation for submission.

Methodology

- **Background on Real-Time Information:**
  - MARTA launched apps in November 2013
  - OneBusAway launched in February 2014

- **Method:** Before-After Analysis of MARTA Trips
  - April 2013 to April 2014

- **Unit of Analysis:** Individual rider

- **Primary Data Source:** Breeze Card smart cards
  - Number of transit trips on bus and train

MARTA's On the Go Apps

Source of Images: itsmarta.com

Smart Card Data

Date: Day determines 'before' & 'after' trips

Mode: Bus + Rail

Spatial Unit: Station (Rail) & Route (Bus)

of: 20-Mar-13 14:44:14
f 3

Metropolitan Atlanta Rapid Transit Authority
pr-nbms3:nextfare
A100 / PN.14-04.2701.04 / 1108

Transit Card Transaction History

l Transit Card: 0160014377218919
cted Start and End Dates and Times: 01/01/13 00:00:00 to 03/20/13 00:00:00
S d Operators:
Sele Facilities:
Selecte ransaction Types:
Selected T nsaction Statuses:
Selected Bus umber(s):

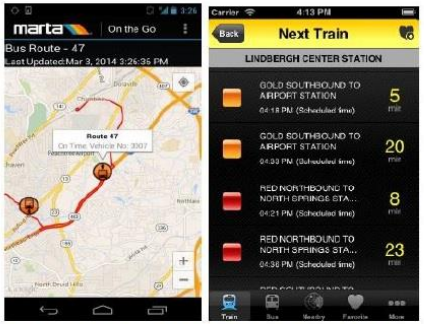
Time / e Id	Bus ID	Operator / Cart ID	Facility / Grp ID	Hi/Lo Zone	Route / Transaction Description	Value Change $	Bonus $	Value Left $	Rides Left	Renewed In Advance Count*	Transaction Status	Card Seq Num
:21 / RVG30621		MARTA Rail / N/A	Lindbergh Center / N/A	N/A / N/A	Pass Entry (Tag On)	0.00		0.00	15	0	Success	2
02-Jan-13 13:35:24 / RVG30717		RTA Rail / N/	Lenox / N/A	N/A / N/A	Pass Exit (Tag Off)	0.00		0.00	15	0	Success	3
02-Jan-13 17:10:36 / RVG30715		MARTA Rail / N/A	Lenox / N/A	N/A / N/A	Pass Entry (Tag On)	0.00		0.00	14	0	Success	4
02-Jan-13 17:25:08 / RVG30413		MARTA Rail / N/A	Midtown / N/A	N/A / N/A	Pass Exit (Tag Off)	0.00		0.00	14	0	Success	5
02-Jan-13 18:50:37 / DCU02349	2345	MARTA Bus / N/A	Perry Garage / N/A	N/A / N/A	North Decatur Road :: N (36) / Pass Transfer	0.00		0.00	14	0	Success	6
04-Jan-13 07:05:50 / DCU10053	2349	MARTA Bus / N/A	Perry Garage / N/A	N/A / N/A	North Decatur Road :: N (36) / Pass Entry (Tag On)	0.00		0.00	13	0	Success	7
04-Jan-13 16:49:26 / DCU02145	2346	MARTA Bus / N/A	Perry Garage / N/A	N/A / N/A	North Decatur Road :: N (36) / Pass Entry (Tag On)	0.00		0.00	12	0	Success	8
07-Feb-13 07:39:04 / DCU10053	2349	MARTA Bus / N/A	Perry Garage / N/A	N/A / N/A	North Decatur Road :: N (36) / Pass Entry (Tag On)	0.00		0.00	11	0	Success	9
07-Feb-13 18:24:06 / DCU02215	2343	MARTA Bus / N/A	Laredo Garage / N/A	N/A / N/A	North Decatur Road :: N (36) / Pass Entry (Tag On)	0.00		0.00	10	0	Success	10
11-Feb-13 07:50:56 / 2330	2360	MARTA Bus / N/A	Hamilton Garage / N/A	N/A / N/A	North Decatur Road :: N (36) / Pass Entry (Tag On)	0.00		0.00	9	0	Success	11

Survey Data

- **Data Collection**
  - Web-based survey conducted first week of May 2014
- **Recruitment**
  - Both real-time information (RTI) users and non-users
- **Matching with Smart Cards**
  - 669 participants entered survey software
  - 538 provided a 16 digit smart card number
  - 494 matched usable, active smart cards

*3. What is your 16-digit Breeze Card number?
Please do not enter spaces or dashes.

MARTA's On the Go Apps



Georgia Tech's OneBusAway Apps

The Transit App

Source of Breeze Card Image: itsmarta.com

Conditions Imposed on the Dataset

- **Initial:** Combined Survey/Smart Card Dataset (n=494)
- **Condition 1**: Panel Eligibility (April 2013 + April 2014)
  - Real-Time (n=431)
  - Smart Card (n=305)
- **Condition 2**: Complete & Unique (One Card = One Person)
  - Complete with One Breeze Card (n=219)
  - Complete with No Other Fare Media (n=193)
  - Unique without Sharing Breeze Card (n=159)
- **Condition 3**: Congruent (That Card = That Person)
  - Closely Congruent (n=135)
  - Perfectly Congruent (n=100)

Before-After Comparison of MARTA Trips

		All Data		Closely Congruent		Perfectly Congruent	
Use of Real-Time Information (RTI)		RTI	No	RTI	No	RTI	No
Count		302	192	60	75	38	62
April 2013*	Mean	$\boxed{10.2}$	$\boxed{4.7}$	15.6	5.7	12.8	4.1
	SD	20.2	14.5	21.7	12.3	22.2	9.4
April 2014*	Mean	21.9	9.6	21.7	7.9	21.1	5.1
	SD	29.3	22.4	27.5	14.7	29.8	10.6
Difference	Mean	$\boxed{11.7}$	$\boxed{4.9}$	$\boxed{6.1}$	$\boxed{2.2}$	$\boxed{8.3}$	$\boxed{1.0}$
	SD	27.8	15.8	25.4	11.3	25.1	8.9
		$t = -3.478$ $\boxed{p=0.0006}$		$t = -1.097$ $\boxed{p=0.276}$		$t = -1.732$ $\boxed{p=0.0905}$	
Total Sample Size		494		135		100	

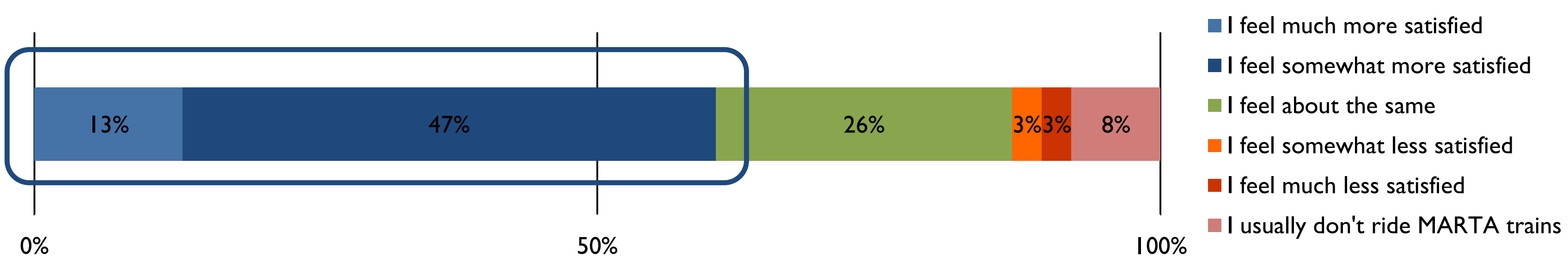
*4 weeks in April 2013 and April 2014 beginning with the first Tuesday of the month.

Perceived Changes: Riding MARTA Trains Perfectly Congruent

- Has using an app with real-time information changed the NUMBERS OF TRIPS that you take on MARTA TRAINS?*

- Has using an app with real-time information changed the amount of time you spend WAITING for MARTA TRAINS?**

- Has using an app with real-time information changed how SATISFIED you are with MARTA TRAIN service?



Sample Size is Real-Time Information Users Meeting Conditions 1A-3B (n= 38) .
*Zero answers for "I ride somewhat less" or "I ride much less". **Zero answers for "I spend much more time waiting" or "I spend somewhat more time waiting.

Atlanta Conclusions

- **Conclusions**
  - Full Dataset (n=494): RTI users increased transit trips
  - Datasets with Conditions: No significant difference between RTI users and non-users
  - Many RTI users perceived a decreased in wait times and increased satisfaction with MARTA service

- **Limitations**
  - Non-probability sampling
  - Decreasing sample size

COMPARISON & CONCLUSIONS

Comparison of Key Findings

	New York City	Tampa	Atlanta
Transit Agency	New York City Transit	HART	marta
Methodology	Natural experiment with panel regression	Behavioral experiment with a before-after control group design	Before-after analysis of transit trips
Key Finding	Average weekday route-level increase of ~118 rides (median of 1.7%); Average weekday increase of ~340 rides on the largest routes (median of 2.3%)	Little evidence supporting a change in bus trips; Significant improvements in the waiting experience, particularly wait times	Little evidence supporting a change in bus/train trips; Perceived improvements in wait times and overall satisfaction with MARTA

Concluding Remarks

Decreased Wait Times

- Atlanta
- Tampa

Increased Satisfaction

- Atlanta
- Tampa

Increased Ridership

- New York City

Perhaps there are increases in ridership where there is the highest level of transit service, attracting "choice" trips.

THANK YOU.

Questions? Email cbrakewood@gmail.com

Acknowledgements:

- The New York City study was co-authored with Gregory Macfarlane and the Tampa study was co-authored with Sean Barbeau; the authors gratefully acknowledge their contributions.
- This work was funded by a US DOT Eisenhower Graduate Fellowship, the National Center for Transit Research (NCTR), the National Center for Transportation Systems Productivity and Management (NCTSPM), and Georgia Tech's GVU Center.
- The authors are very grateful to the MTA in New York City, HART in Tampa, and MARTA in Atlanta for their support of this research.
- Finally, the authors owe a tremendous amount of gratitude to the many people who have contributed to OneBusAway open source project over the years, particularly Brian Ferris.