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Shaping the world since 1929

Measuring Rail Transit's Sustainability Goals:

A Before-After, Experimental-Control Evaluation of Los Angeles' Expo Light Rail Line

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Changing Times

Transportation used to be this:

Source: KCET SoCal Focus, http://www.kcet.org/updaily/socal_focus/history/la-as-subject/before-the-carmageddon-a-photographic-look-at-the-construction-of-5-socal-freeways-35191.html

But has become this:

Sources: http://www.ciclavia.org/about/, http://www.bikelongbeach.org/News/Read.aspx?ArticleId=85, : http://park101.org/, http://laecovillage.wordpress.com/2010/06/04/lovely-long-beach-bike-lanes/, and Western Riverside Council of Governments.

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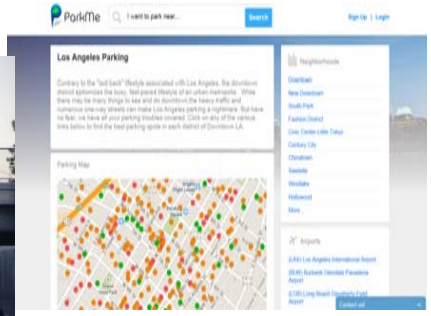
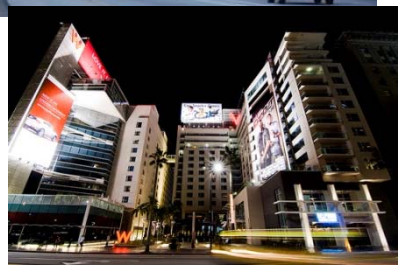
From "Car Only" to Variations on a Theme

Return of Local, Innovative, Transportation Programs





Source: lastreetsblog.com

http://www.parkme.com/la-parking, thesoucre.metro.net , sigalert.com

Return of the Market (a hybrid sector)

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Research for an Era of Locally Innovative Transportation

- High occupancy toll lanes
- Real time parking pricing
- Bicycle sharing
- Neighborhood electric vehicles
- Pedestrian mall
- Traffic calming
- Employer provided transit pass

- Los Angeles' rail transformation
  - Six new lines opening between 2012 and 2020
  - Expo Line Phase I is the first of the six
  - When complete: Los Angeles MTA rail system will be larger than Washington Metro
- California Senate Bill 375 (2008)
  - SCAG: 8% reduction by 2020; 13% reduction by 2035

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Program Evaluation

- Before-After, Experimental-Control Group study of rail transit impact
- Motivation:
  - Better evidence on causal impact of rail
  - Estimate of magnitude of impact
  - Pilot test program evaluation more generally
- Previous similar studies in:
  - Charlotte (McDonald et al., 2010)
  - Salt Lake City (Brown and Werner, 2008)
  - Seattle (in progress, Saelens et al., U of Washington)

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Expo Line Study

1. Study Area
2. Survey Waves and Survey Methods
3. Variables
4. Study Design
5. Results

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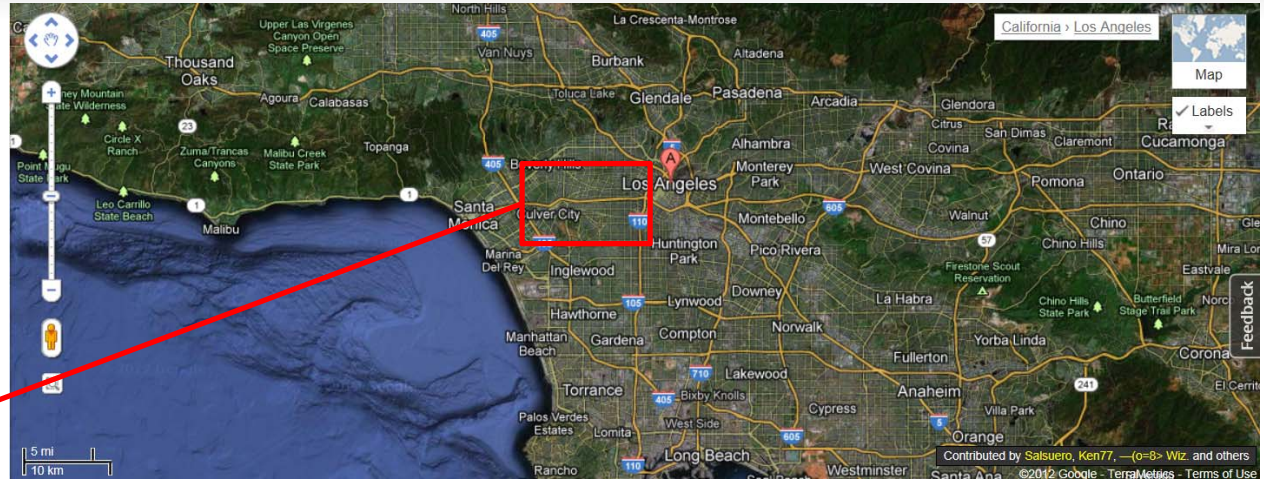
Study Area: Background, Expo Line



Source: Google Maps

Source: L.A. Metro

Phase I, opened April 28, 2012 (Culver City station opened June 20, 2012)

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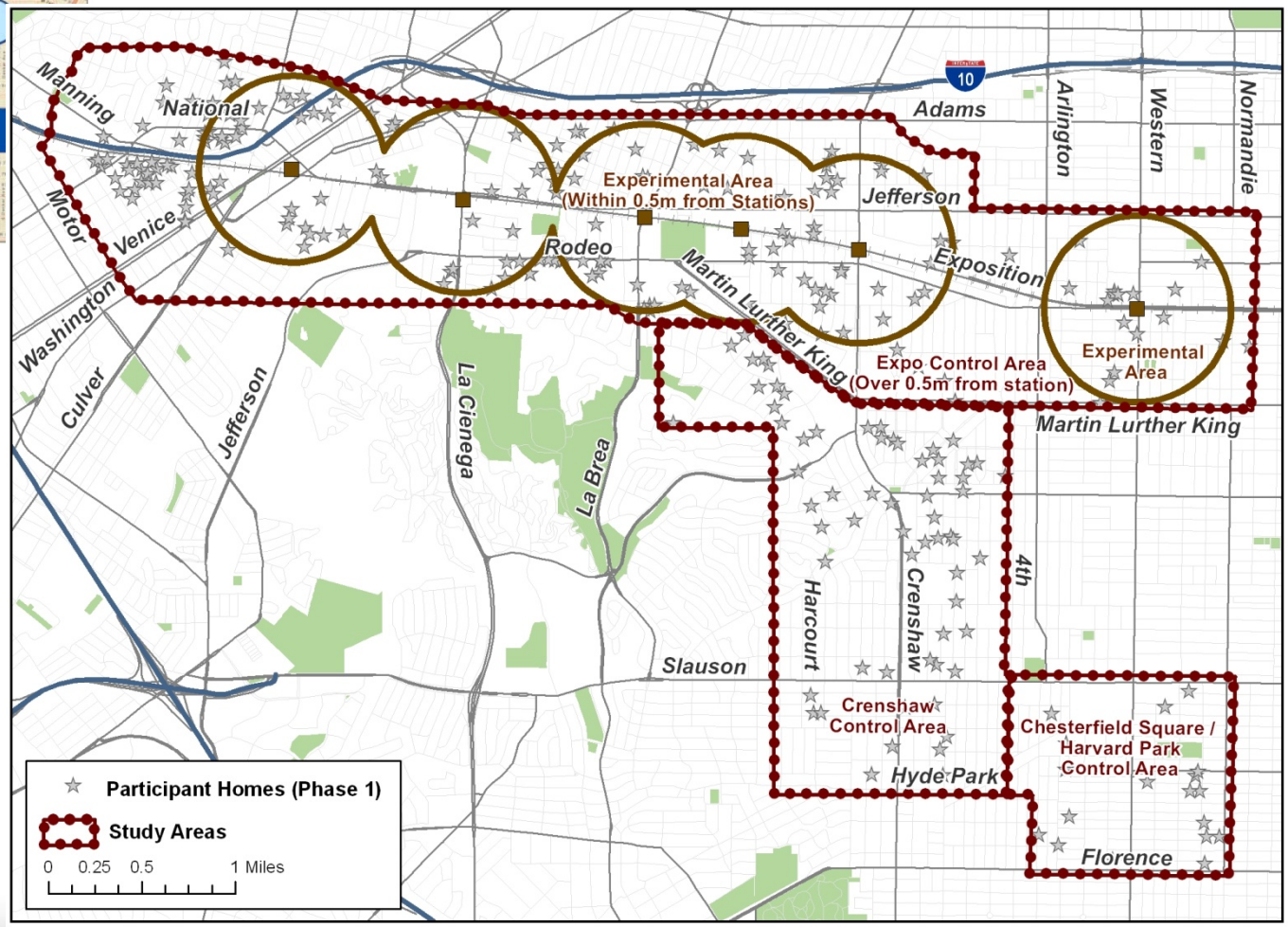
Study Area Selection, Summer 2011



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Survey Waves

- Wave 1, Sept., 2011 – Jan. 2012 (3 to 7 months before opening)
  - 284 households
- Wave 2, Sept., 2012 – Jan. 2013 (5 to 8 months after opening)
  - 204 households as of Dec. 20, 2012
  - A true panel study; only households from Wave 1 recontacted
- Wave 3, fall 2013 (174 households)

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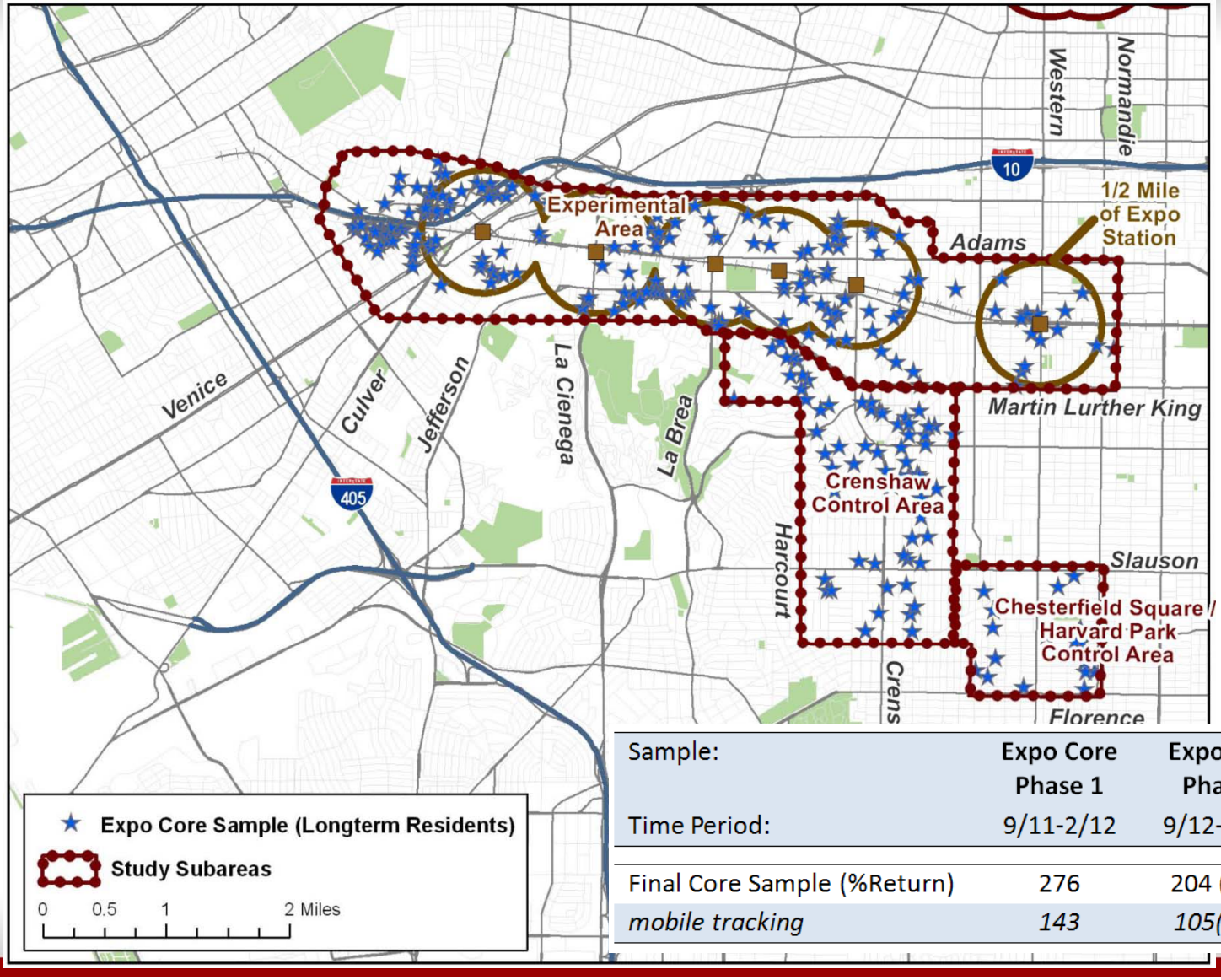
Study Subjects



Sample:	Expo Core Phase 1	Expo Core Phase 2	Expo Core Phase 3
Time Period:	9/11-2/12	9/12-11/12	9/13-11/13
Final Core Sample (%Return)	276	204 (71%)	174 (83%)
mobile tracking	*143*	*105(73%)*	*83 (79%)*

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Survey Methods

- 7-day travel diary, all household members 12 and older
- Household and individual sociodemographics
  - Income, car ownership, etc.
- Attitudes toward environment, safety

- In 141 households (Wave 1), 1 adult carried a GPS and accelerometer

Activity Level Meter: right above your **right** hipbone, snug again your body.

GPS: You can wear your location tracking device on your own belt with the pocket you have received.

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Survey Methods

Neighborhood Travel and Activity Study

Travel Log

Person Name:

	Car Driver	Car Pass-enger	Motor-cycle/ Scooter	Bus	Train	Bicycle		Walk		Other	Notes? Problems? Please describe below.
						# of Trips	Total Minutes	# of Trips	Total Minutes		
Monday											
Tuesday											
Wednesday											
Thursday											
Friday											
Saturday											
Sunday											

Instructions

- Count each trip you take during each day
- Include walk/bike trips over 5 minutes
- Count trips you take for recreation or exercise
- Log the total minutes you walk or bicycle each day
- Count each trip mode as a separate trip (car, walk, etc)

Suggestions

- Carry and complete the log as you travel
- Or you can complete the log at the end of each day
- Note any problems each day (forgot to fill out one day)
- See the back of this log for examples

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Survey Methods

Neighborhood Travel and Activity Study

Vehicle Mileage Log

Vehicle Year: _____

Make (Ford, Honda, etc): _____

Model (Focus, Accord, etc): _____

	Start	End
Monday		
Tuesday		
Wednesday		
Thursday		
Friday		
Saturday		
Sunday		

Instructions

- Place one log in each vehicle in a visible location
- Enter vehicle year, make, and model
- Log mileage at the start and end of each day
- Obtain mileage from the *odometer* near the speedometer

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Dependent Variables

- Self-Reported:
  - Daily VMT (for HH and persons in HH)
  - Daily # of car trips (for HH and person, driver and passenger)
  - Daily transit trips – bus and rail transit
  - Daily walk trips
  - Daily bike trips
  - Daily walk minutes
  - Daily bike minutes
- Plus:
  - Accelerometer moderate-vigorous PA minutes
  - GPS trace (route)

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Study Design

$$Effect = (\bar{Y}_e - \bar{Y}_c)_{after} - (\bar{Y}_e - \bar{Y}_c)_{before}$$

- *Effect* = effect of Expo Line on travel behavior
  - "e" indexes experimental group
  - "c" indexes control group
  - "after" and "before" indicate after opening and before opening

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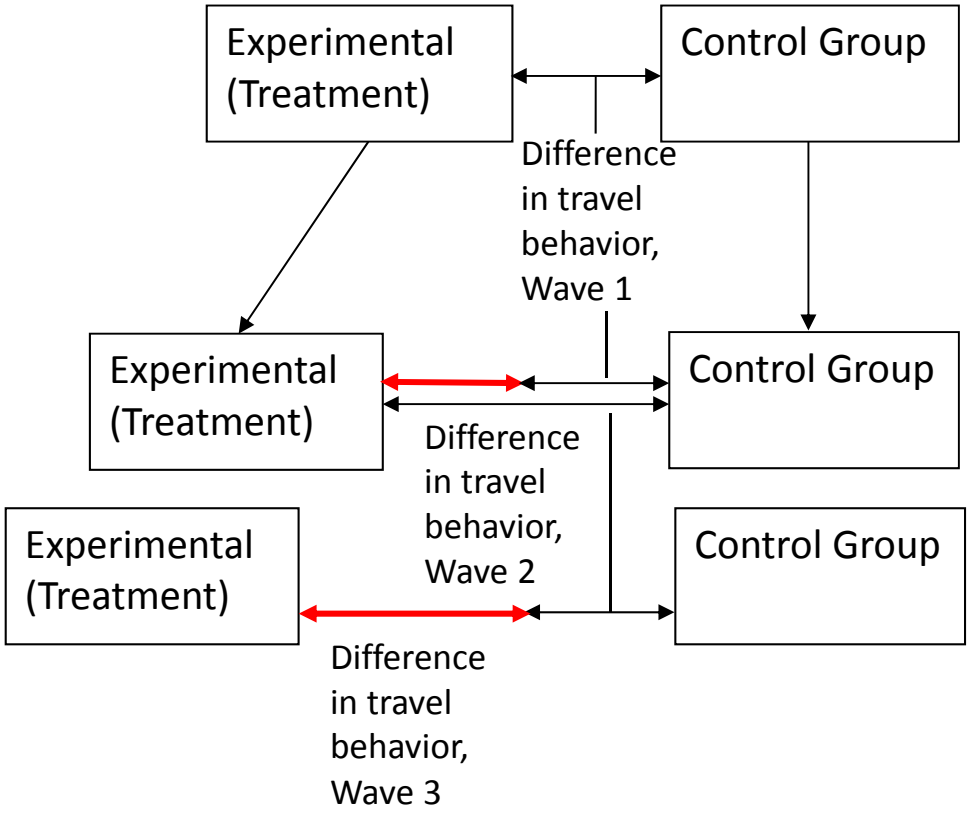
Study Design



Wave 1
(6 mo's before opening)
N = 284 households

Wave 2
(6 mo's after opening)
N = 204 households

Wave 3
(6 mo's after opening)
N = 174 households

Effect of Expo Line on Travel Behavior (Treatment Effect)

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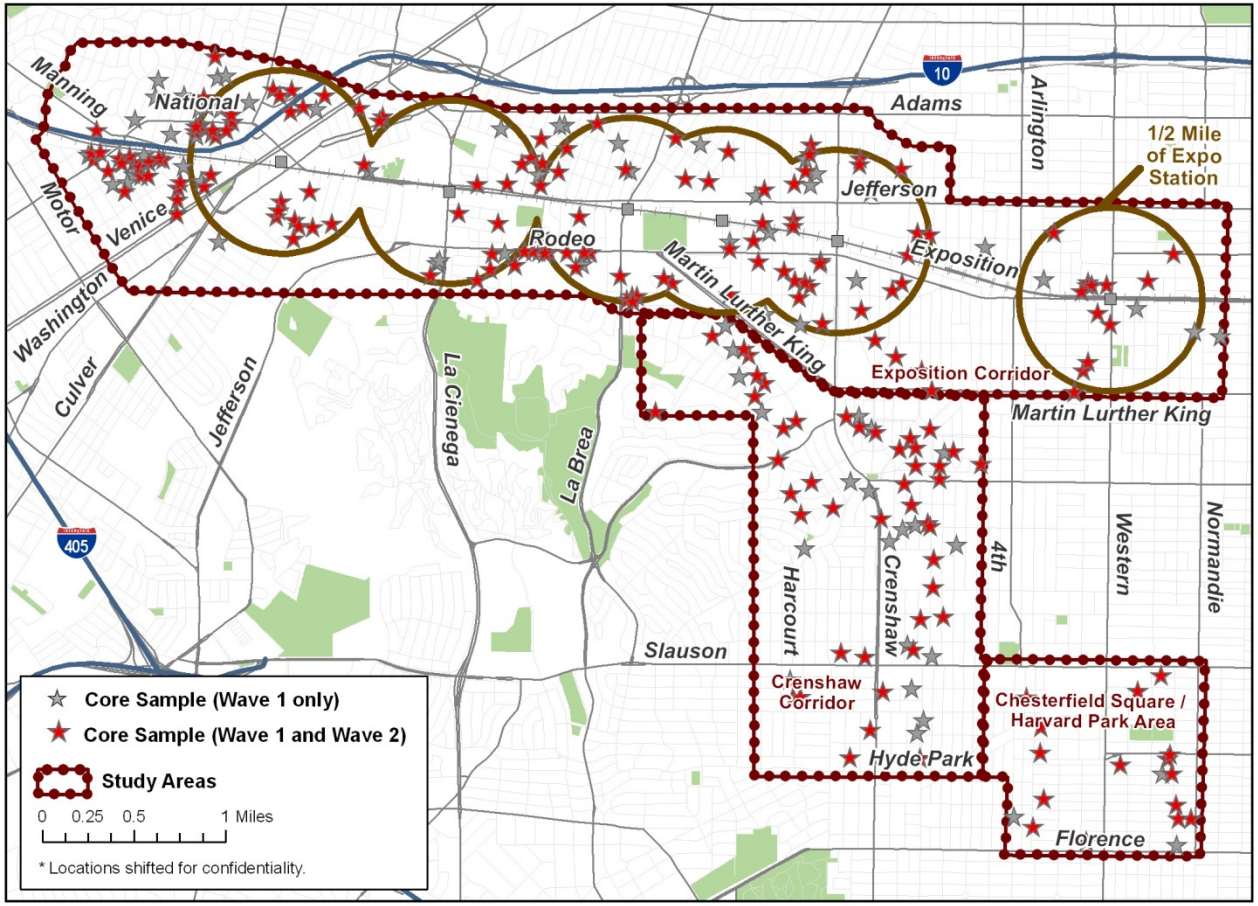
Wave 1 and 2 Data



Wave 1 and Wave 2 data

Response Type	**Complete Responses**
Mobile Tracking	106
Self-Report only	98
Total	204
Group	
Control	101
Experimental	103
Total	204

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Three Questions

1. Are the data reasonable compared to other similar travel data?
2. Are there differences, experimental vs. control, before opening?
3. Are there differences, experimental vs. control, after opening?

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Question 1: Are the Data Reasonable?

Comparison of Expo Before Opening and NHTS

	Expo Line Study Area		NHTS within Study Area		NHTS LA County	
Travel Outcome Variable	***mean***	***N***	***mean***	***N***	***mean***	***N***
Daily Vehicle Miles Traveled	27.13	276	24.89	50	40.75	3073
Daily Car Trips (Driver+Passenger)	4.50	288	5.76	50	6.94	3082
Daily Bus Trips	0.60	288	0.60	50	0.24	3082
Daily Train Trips	0.07	288	0.04	50	0.02	3082
Daily Transit Trips	0.67	288	0.56	50	0.21	3082
Daily Bike Trips	0.18	288	0.10	50	0.10	3082
Daily Walk Trips	1.65	288	0.98	50	1.23	3082

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Results

	Study Group	6 months before Mean	6 months before Mean Diff.	6 months before t	6 months before Sig.	6 months after Mean	6 months after Mean Diff.	6 months after t	6 months after Sig.	18 months after Mean	18 months after Mean Diff.	18 months after t	18 months after Sig.
VMT	exp	27.29	0.26	0.59		22.57	-6.67	-1.66	°	23.72	-10.71	-2.06	*
	control	27.03				29.24				34.43			
Train trips	exp	0.06	0	0.05		0.26	0.22	3.29	**	0.3	0.21	2.49	*
	control	0.06				0.04				0.09			
Total Transit Trips	exp	0.69	0.11	0.49		0.82	0.23	1.06		0.74	0.15	0.66	
	control	0.58				0.59				0.59			

Significance codes: ** < 0.01, * < 0.05, ° < 0.10

Note: All values are per household daily trip frequencies or VMT.

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Results

	Study Group	6 months before Mean	6 months before Mean Diff.	6 months before t	6 months before Sig.	6 months after Mean	6 months after Mean Diff.	6 months after t	6 months after Sig.	18 months after Mean	18 months after Mean Diff.	18 months after t	18 months after Sig.
VMT	exp	27.29	0.26	0.59		22.57	-6.67	-1.66	°	23.72	-10.71	-2.06	*
	control	27.03				29.24				34.43			
Train trips	exp	0.06	0	0.05		0.26	0.22	3.29	**	0.3	0.21	2.49	*
	control	0.06				0.04				0.09			
Total Transit Trips	exp	0.69	0.11	0.49		0.82	0.23	1.06		0.74	0.15	0.66	
	control	0.58				0.59				0.59			

Significance codes: ** < 0.01, * < 0.05, ° < 0.10

Note: All values are per household daily trip frequencies or VMT.

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Controlling for number of persons in the household, number of vehicles, and income

Travel Outcome	6 mo. After	t	Sig.	18 mo. After	t	Sig.	N
VMT	-5.77	-1.15		-9.87	-1.96	*	435
Car Driver Trips	-0.02	-0.44		-0.21	-0.38		471
Car Passenger Trips	0.04	0.12		-0.09	-0.26		489
Bus Trips	-0.21	-0.89		-0.12	-0.49		489
Train Trips	0.19	1.78	°	0.21	1.94	°	489
Total Transit Trips	-0.02	-0.07		0.09	0.32		489
Active (Walk + Bike) Trips	0.03	0.06		-0.41	-0.88		483
Total Trips	-0.21	-0.21		-0.81	-0.81		465

Significance Codes: * < 0.05, ° < 0.10

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Rail Riders Reduce Car Trip Length

	6 Months Before Opening			6 Months After Opening			18 Months After Opening		
	Train Users (n = 16, 9.3%) Mean	Non-train Users (n =156, 90.7%) Mean	Sig.	Train Users (n = 32, 18.7%) Mean	Non-train Users (n =139, 81.3%) Mean	Sig.	Train Users (n = 35, 20.3%) Mean	Non-train Users (n = 138, 79.7%) Mean	Sig.
Car Trip Length	11.12	10.3		7.8	8.98		4.03	9.71	*
Cars Available	0.75	1.34	**	1.09	1.32		1.09	1.39	°
Household Income ($1,000)	25	48.59	**	44.91	47.97		39.63	48.86	°
Significance Codes: * < 0.001, ** < 0.01, * < 0.05, ° < 0.10**									

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And Rail Riders Became More Like Non-Riders

	6 Months Before Opening			6 Months After Opening			18 Months After Opening		
	Train Users (n = 16, 9.3%) Mean	Non-train Users (n =156, 90.7%) Mean	Sig.	Train Users (n = 32, 18.7%) Mean	Non-train Users (n =139, 81.3%) Mean	Sig.	Train Users (n = 35, 20.3%) Mean	Non-train Users (n = 138, 79.7%) Mean	Sig.
Car Trip Length	11.12	10.3		7.8	8.98		4.03	9.71	*
Cars Available	0.75	1.34	**	1.09	1.32		1.09	1.39	°
Household Income ($1,000)	25	48.59	**	44.91	47.97		39.63	48.86	°
Significance Codes: * < 0.001, ** < 0.01, * < 0.05, ° < 0.10**									

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Shorter Car Trips are More Important than Rail Displacing Car Trips

1. Rail Trips Displace Car Trips				Fraction of Total VMT Reduction
Effect Size	**Car Trip Length**	**Effect Calculation**	**Effect**	
-0.21 trips per day	9.37 miles/trip	9.37 miles/trip * 0.21 trips per day	-1.97 daily miles	**19.95%**
Change in rail trips	*experimental, Wave 1, car trip length*			
2. Car Trips Get Shorter				
Effect Size	**Penetration**	**Effect Calculation**	**Effect**	
-7.09 miles/trip	20.30%	penetration (20.3%) * effect size (-6.92 miles/trip) * number of car trips (3.3 car trips per day, experimental, before opening)	-4.75 daily miles	**48.13%**
Change in car trip length for rail riders	*Fraction rail riders among experimental group*			

Fraction of 9.87 household miles per day VMT reduction

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Results

- Daily household VMT drops by about 10 miles per day (average for study group ≅ 27 miles per day)
- VMT drop (relative to control group) persists in Wave 3, more than 1 year after opening
- Increases in rail trips (more than doubled), experimental vs. control
- Two thirds of the VMT reduction can be attributed to shorter car trips and eliminated driving trips among rail riders

Accelerometer Data Processing

- 131 persons carried Actigraph 3GTX accelerometer
- Processed raw data (counts) using MeterPlus software
- Two steps (following Freedson et al., 1998):
  - Data reduction: eliminate outliers and non-valid data
  - Data calibration: relate counts to minutes of moderate and vigorous physical activity and KCals

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Descriptive Summary

	Survey Sample (*N*=204)				Mobile Sample (*N*=73)			
	Time 1 (Baseline)		Time 2 (Follow-up)		Time 1 (Baseline)		Time 2 (Follow-up)	
	Treatment (*N*=101)	Control (*N*=103)	Treatment (*N*=101)	Control (*N*=103)	Treatment (*N*=32)	Control (*N*=41)	Treatment (*N*=32)	Control (*N*=41)
	Mean (SD) or %	Mean (SD) or %	Mean (SD) or %	Mean (SD) or %	Mean (SD) or %	Mean (SD) or %	Mean (SD) or %	Mean (SD) or %
Average daily train trips	0.36 (1.76)	0.20 (0.81)	1.50 (3.39)	0.23 (1.24)	0.01 (0.07)	0.05 (0.15)	0.24 (0.58)	0.01 (0.07)
Average daily bus trips	3.13 (6.34)	2.23 (5.76)	2.77 (6.40)	1.83 (4.79)	0.32 (0.62)	0.43 (0.95)	0.46 (0.98)	0.24 (0.54)
Average daily MVPA minutes					23.09 (17.49)	19.81 (18.01)	21.52 (16.24)	18.56 (17.02)
Average daily walk trips	7.00 (7.19)	4.66 (6.06)	8.56 (11.29)	5.49 (7.54)				

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Physical Activity + Walk Trip Model

$$Y_{2,i} = \beta_0 + \beta_1 Y_{1,i} + \beta_2 T_i + \beta_3 \left(Y_{1,i} \times T_i\right) + X_i' \gamma + \varepsilon_{i,t}$$

Where,

$Y_{2,i}$ is an active travel outcome (MVPA minutes and walk trips) for individual *i* at Time 2 (follow-up or "after opening" survey);
$Y_{1,i}$ is an active travel outcome for individual *i* at Time 1 (baseline or "before opening" survey);
T_i is the treatment condition dummy variable, equal to 1 for individuals living within ½ mile of an Expo Line light rail and 0 for the control group living farther than ½ mile from a station;
X_i' represents the set of covariates, including transit usage and demographics; $\varepsilon_{i,t}$ is the error term.

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Physical Activity Model Results

Variable	Model 1		Model 2		Model 3	
	β	*p*	β	*p*	β	*p*
Treatment (within ½ mile = 1)	1.89	0.547	9.29	0.066	7.90	0.088
Baseline MVPA	0.47	<0.001	0.60	<0.001	0.60	<0.001
Treatment × Baseline MVPA			-0.34	0.063	-0.37	0.026
Train usage (increased trips = 1)					3.14	0.516
Bus usage (increased trips = 1)					14.63	<0.001
Age (20-84 y)	-0.19	0.126	-0.20	0.102	-0.24	0.038
Gender (male = 1)	8.91	0.010	10.06	0.004	8.51	0.009
Household income (below 35k = 1)	1.52	0.636	2.42	0.450	-0.42	0.889
Employment (employed = 1)	3.75	0.267	3.83	0.249	3.28	0.278
N		73		73		72
R^2		0.44		0.47		0.59
Adjusted R^2		0.38		0.41		0.53

* p < 0.10, ** p < 0.05, *** p < 0.01

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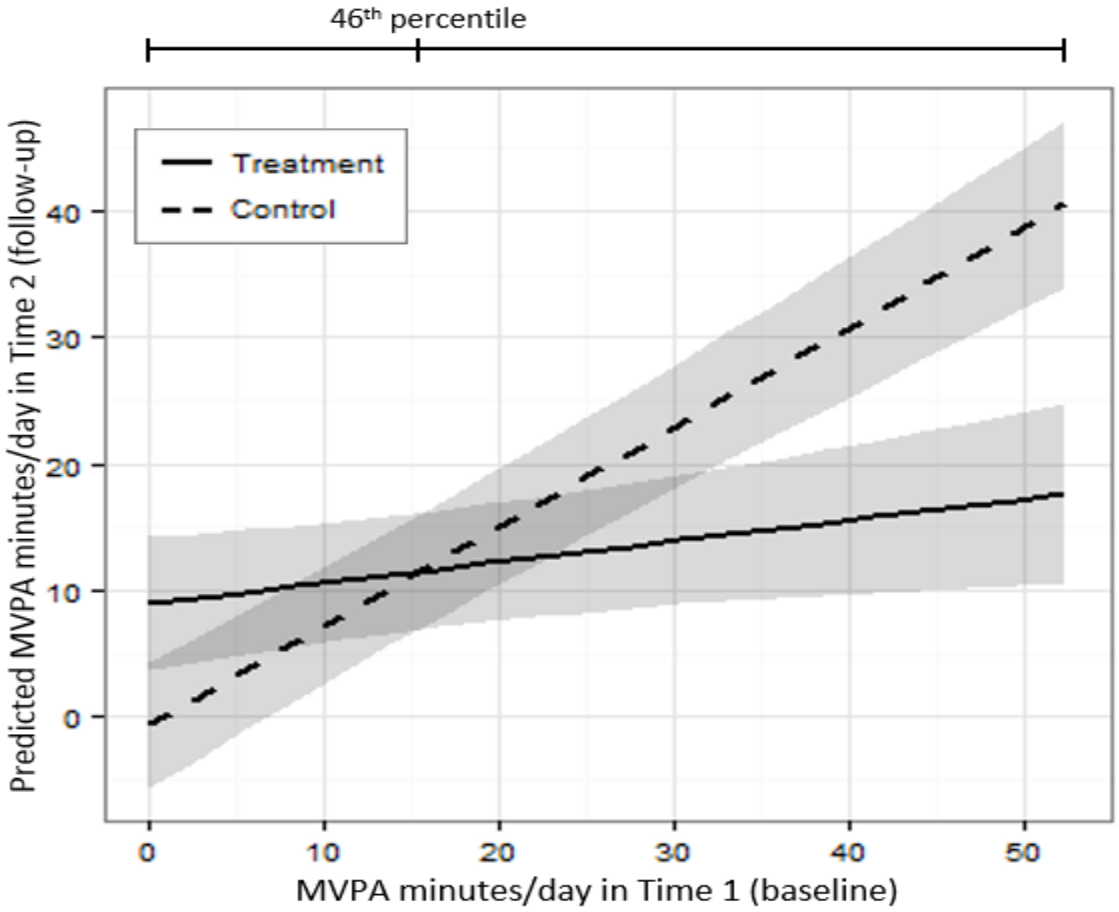
Physical Activity Model Results

Moderating effect of past behavior on treatment



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Walk Trip Model Results

Variable	Poisson Model		Negative Binomial Model	
	β	*p*	β	*p*
Treatment (within ½ mile = 1)	0.27	0.001	0.52	0.021
Baseline walk trips	0.05	<0.001	0.09	<0.001
Treatment × Baseline walk trips	-0.02	0.008	-0.05	0.019
Train usage (increased trips = 1)	0.54	<0.001	0.51	0.026
Bus usage (increased trips = 1)	0.51	<0.001	0.70	0.001
Age (20-84 y)	0.00	0.189	0.00	0.914
Gender (male = 1)	0.12	0.049	0.07	0.724
Household income (below 35k = 1)	0.35	<0.001	0.28	0.135
Employment (employed = 1)	0.27	<0.001	0.08	0.669
N		200		200
Log-likelihood		-875.6		-551.2
AIC		9.2		5.6
BIC		814.3		101.1

Note. The dependent variable is a total walk trip count in Time 2. Four subjects with partial data were excluded from all models.

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More Information

- Final Report to Haynes Foundation

http://priceschool.usc.edu/expo-line-study/

- Final Report to Lincoln Institute of Land Policy

https://www.lincolninst.edu/pubs/2334_The-Exposition-Light-Rail-Line-Study

- Final Report to USC Lusk Center for Real Estate

http://lusk.usc.edu/research/working-papers/does-light-rail-transit-increase-physical-activity

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Thank you to:

Our funders:

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- Lincoln Institute of Land Policy
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- Southern California Association of Governments
- UC Transportation Center
- UC Multi-Campus Research Program on Sustainable Transportation
- USC Lusk Center for Real Estate

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  - USC Ph.D. students: Andy Hong, Xize Wang, Sandip Chakrabarti, Jeongwoo Lee
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