Effects of Complete Streets on Travel Behavior and Exposure to Vehicular Emissions

Principal Investigator:

Yifang Zhu, PhD

Associate Professor

Department of Environmental Health Sciences

UCLA Fielding School of Public Health

Co- Principal Investigator:

Rui Wang, PhD

Assistant Professor

Department of Urban Planning

UCLA Luskin School of Public Affairs

Background & Introduction

Complete streets

Background & Introduction

The Complete Streets Movement

- In September 2008, California passed Assembly Bill (AB) 1358, the Complete Streets Act.
- It encourages people to decrease their dependence on driving passenger vehicles, reducing vehicle miles traveled and associated emissions, enhancing active travel, and reducing transportation costs.
- There is little evidence on whether and how complete streets result in travel behavior changes, which generate claimed benefits.

Objectives

The ***Overall Objective*** of this study is to understand how complete streets as compared to incomplete streets impact travel behavior and non-motorized street users' exposure to vehicular emissions.

Specific Objectives

- Understand the extent to which complete streets affect travel behavior of local residents;
- Illustrate how such effects may vary across different typical land use contexts and road types;
- Explore potential barriers preventing people from using complete streets; and
- Compare non-motorized street users' (e.g., cyclists and pedestrians) exposure to $PM_{2.5}$ and ultrafine particles on complete and incomplete streets.

Study Design --- Overview

- **Two empirical strategies:**
  - A natural experimental design using before-after comparisons
  - A quasi-experimental design using a spatial difference-in-differences (DID) approach

- **Eight pairs of complete and incomplete streets:**
  - Two pairs for before-after comparisons
  - Six pairs for DID in
    - Downtown business district
    - Urban mixed-use area
    - Suburban residential area

Methods : Before-After Study

Site 1: Ocean Park Boulevard

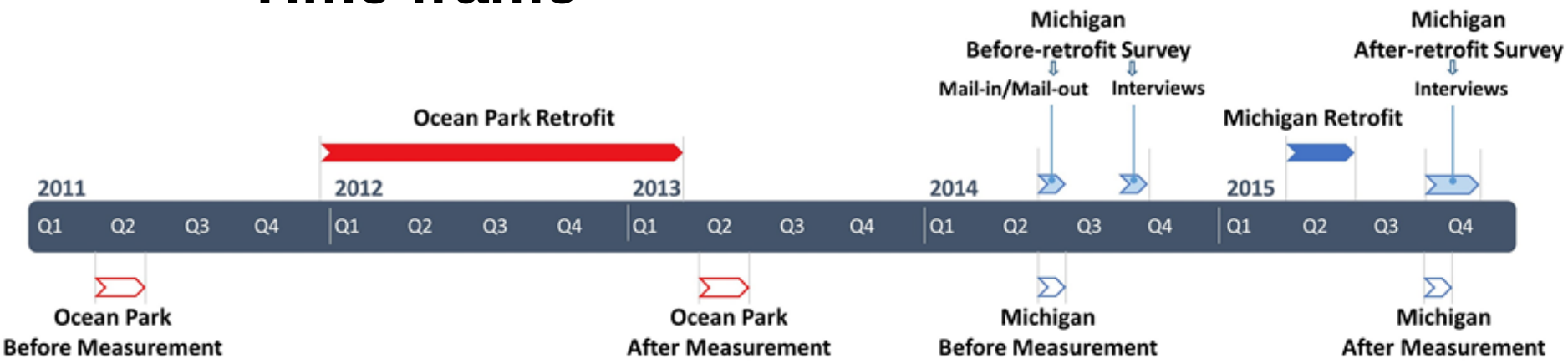
Methods : Before-After Study

Methods : Before-After Study

Site 2: Michigan Avenue Neighborhood Greenway (MANGo) Project

Methods : Before-After Study

Time frame



- **Ocean Park: 14 test days in total**
  - **9 Days Before + 5 Days After**
- **MANGo: 4 test days in total**
  - **2 Days Before + 2 Days After**
- **Three two-hour sessions each test day**

  Morning **Noon** **Afternoon**

Methods : Before-After Study

Vehicular Traffic volume measurements

- **Video footage**
  - **For each session, eight pieces of five-min video**

- **Manual counting & classification**

Methods : Before-After Study

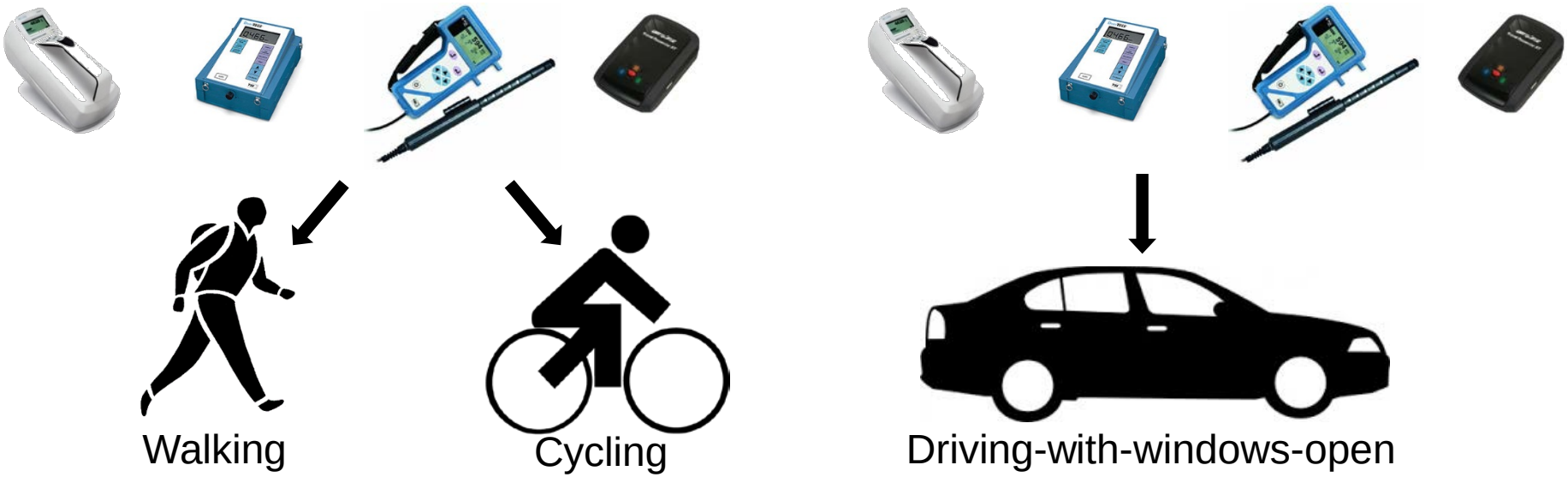
Pedestrians & Cyclists volume

- Manual counting
- Same frequency as video footages

Methods : Before-After Study

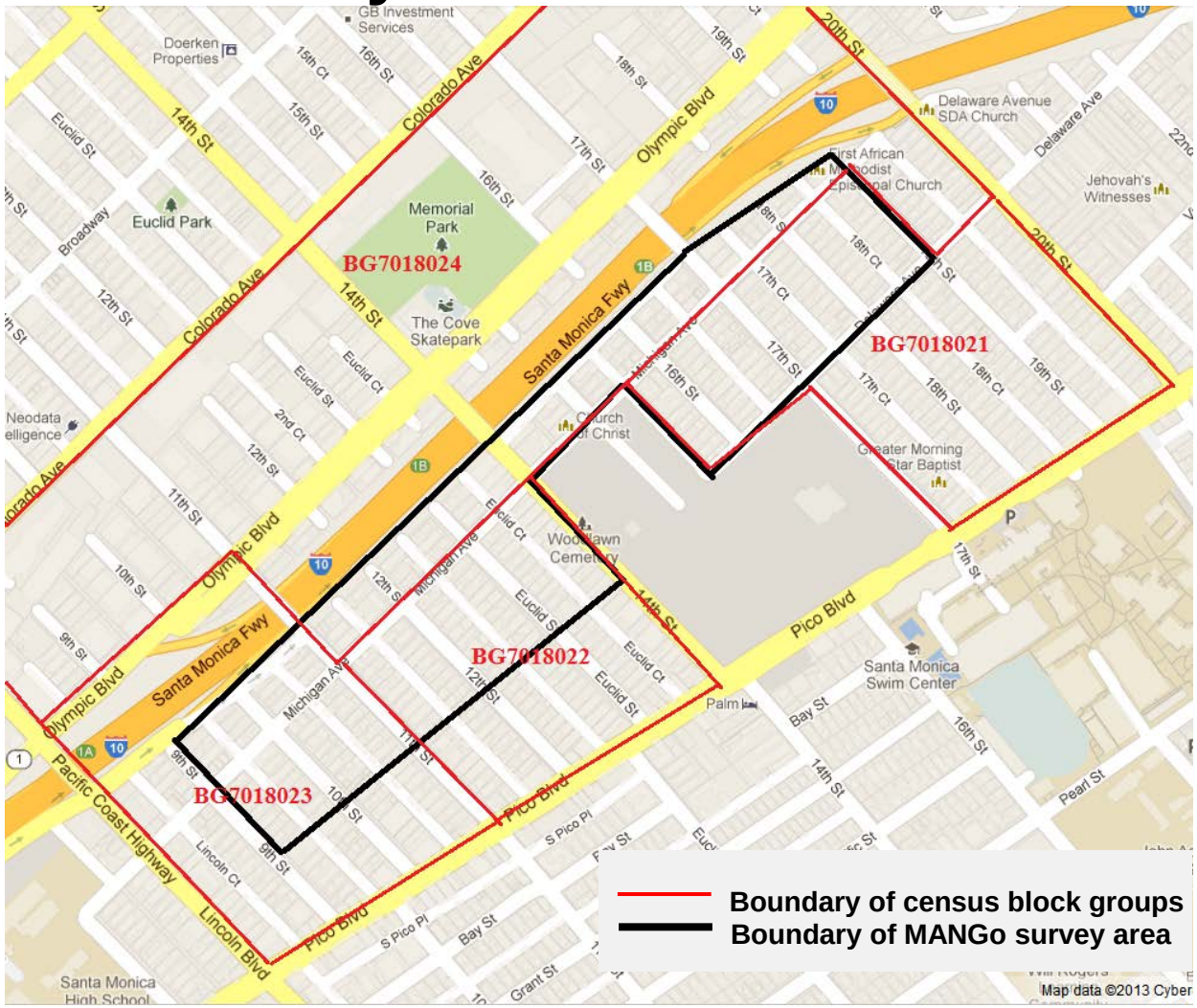
On-road air quality measurements

- Three modes
- Two sets of instruments
- Used a nearby location as ‘background’
  - Ocean Park → Beach site
  - MANGo → Cemetery



Methods : Before-After Study

MANGo survey



Methods : Before-After Study

MANGo survey

- Up to 2 persons in each household
  - At least 1 adult

- Two major components:
  1) Travel behavioral change
  2) Perceived barriers to walking, bicycling, and public transit

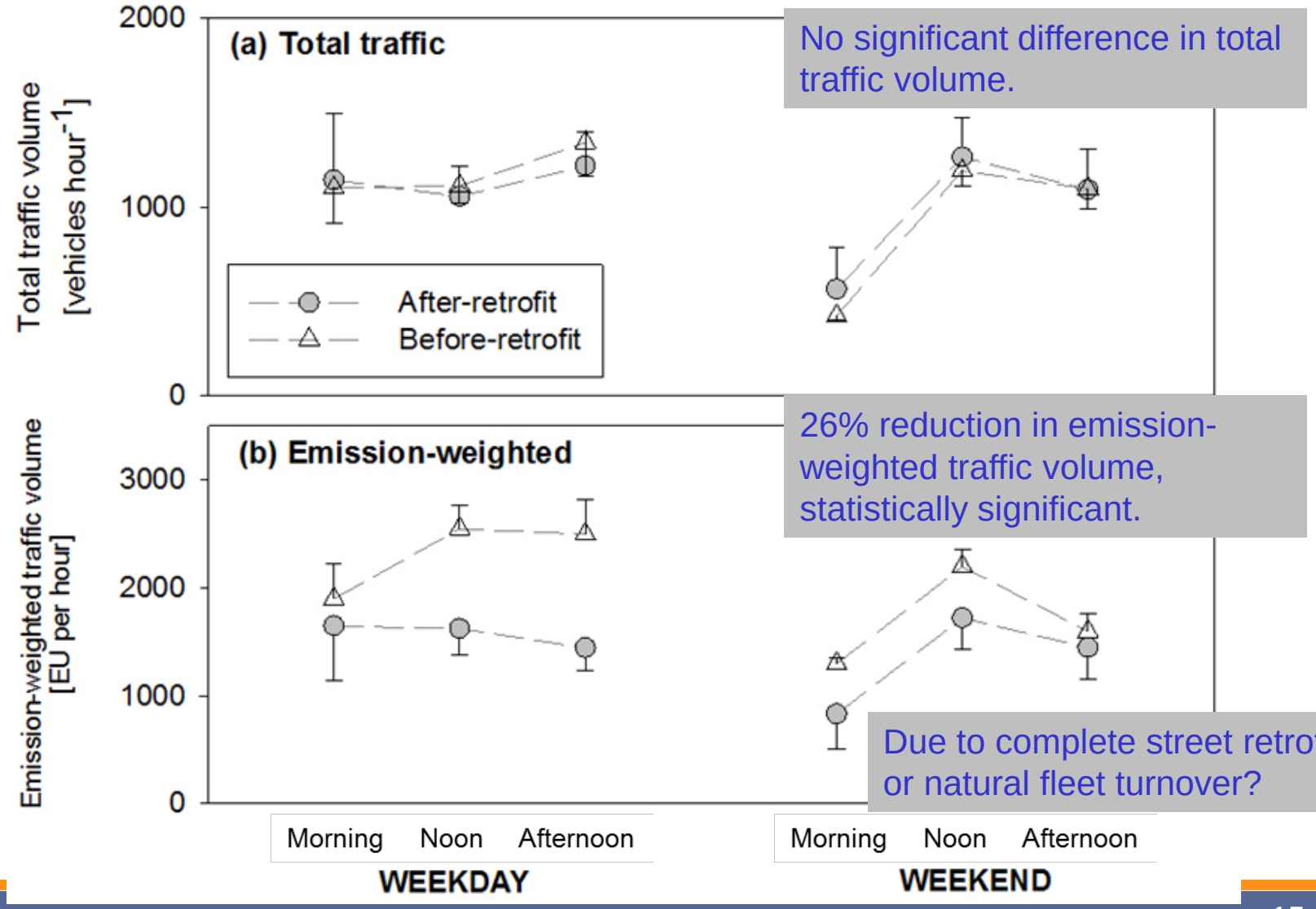
Methods : Before-After Study

MANGo survey

- **Before-retrofit:**
  - **Mail-in/Mail-out to 600 random households**
  - **In-home interview of non-responding households**
- **After-retrofit:**
  - **Same 600 address**
  - **In-home interview only**
- **Statistical analysis**
  - **Ordered logit regression (non-linear)**
  - **Ordinary least squares regression (linear)**

Results: Before-After Study

Site 1: Ocean Park Boulevard



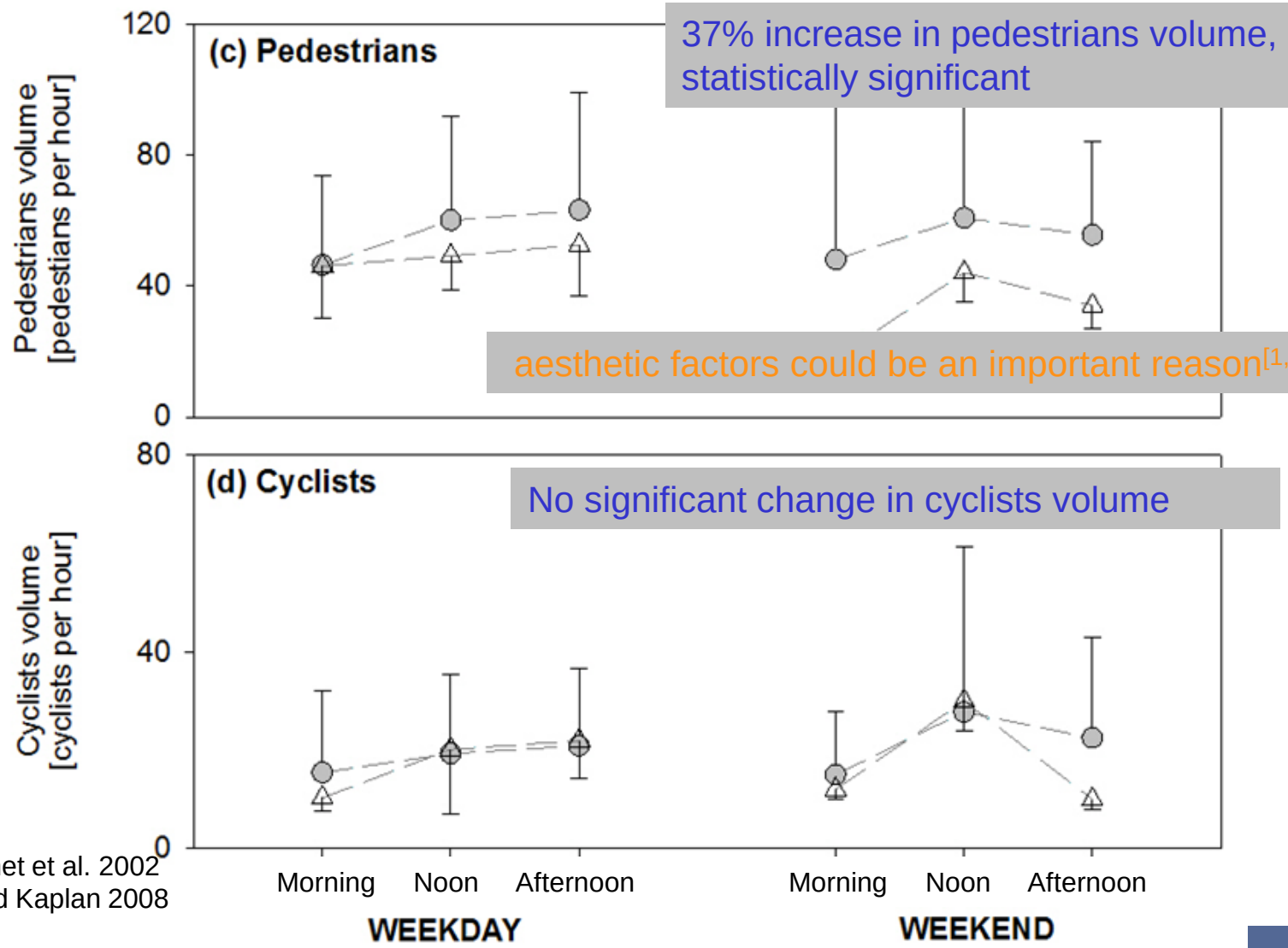
No significant difference in total traffic volume.

26% reduction in emission-weighted traffic volume, statistically significant.

Due to complete street retrofit or natural fleet turnover?

Results: Before-After Study

Site 1: Ocean Park Boulevard



37% increase in pedestrians volume, statistically significant

aesthetic factors could be an important reason[1,2]

No significant change in cyclists volume

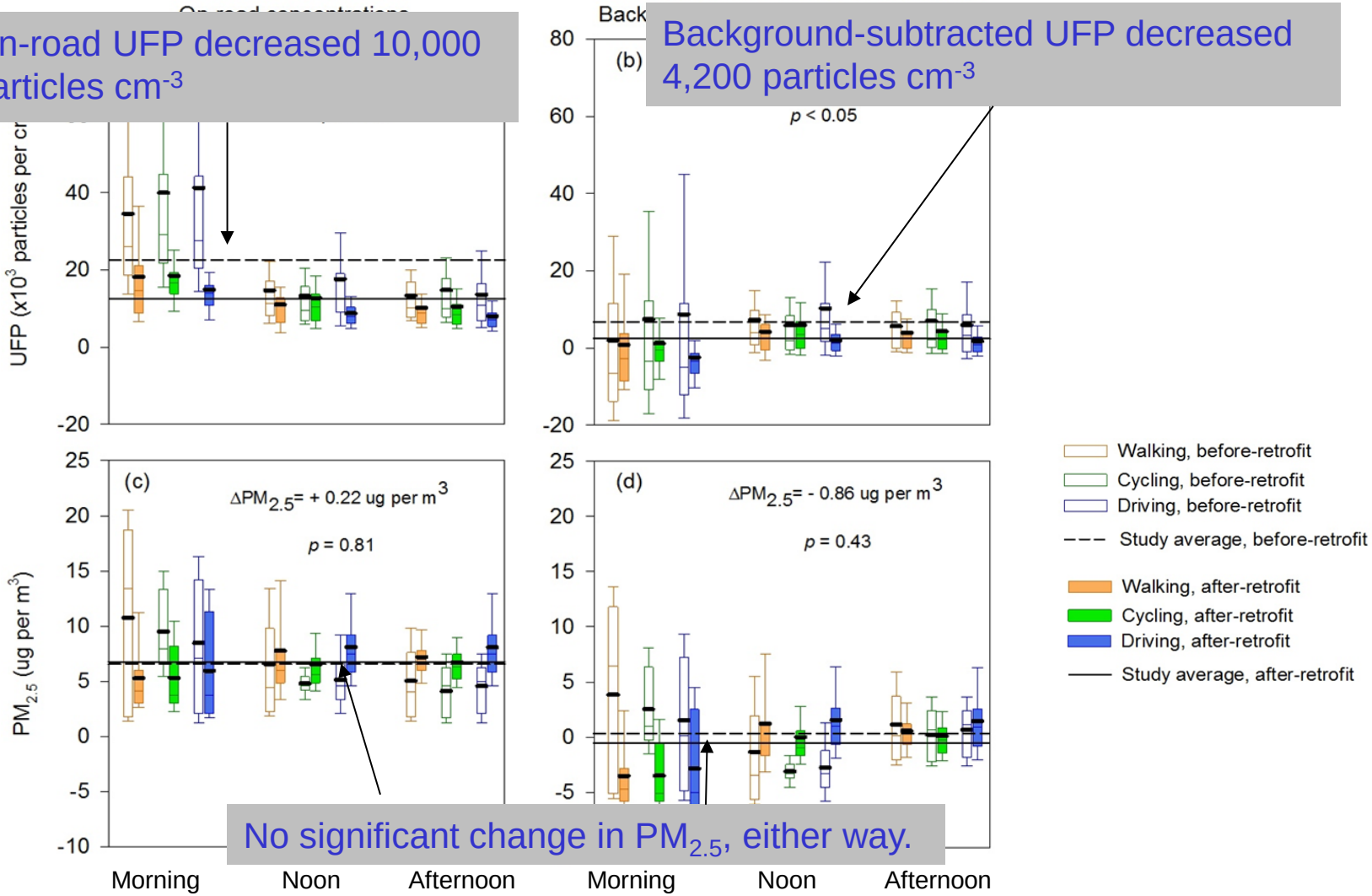
[1] Handy, Boarnet et al. 2002
[2] Matsuoka and Kaplan 2008

Results: Before-After Study

- **Site 1: Ocean Park Boulevard**

On-road UFP decreased 10,000 particles cm^{-3}

Background-subtracted UFP decreased 4,200 particles cm^{-3}

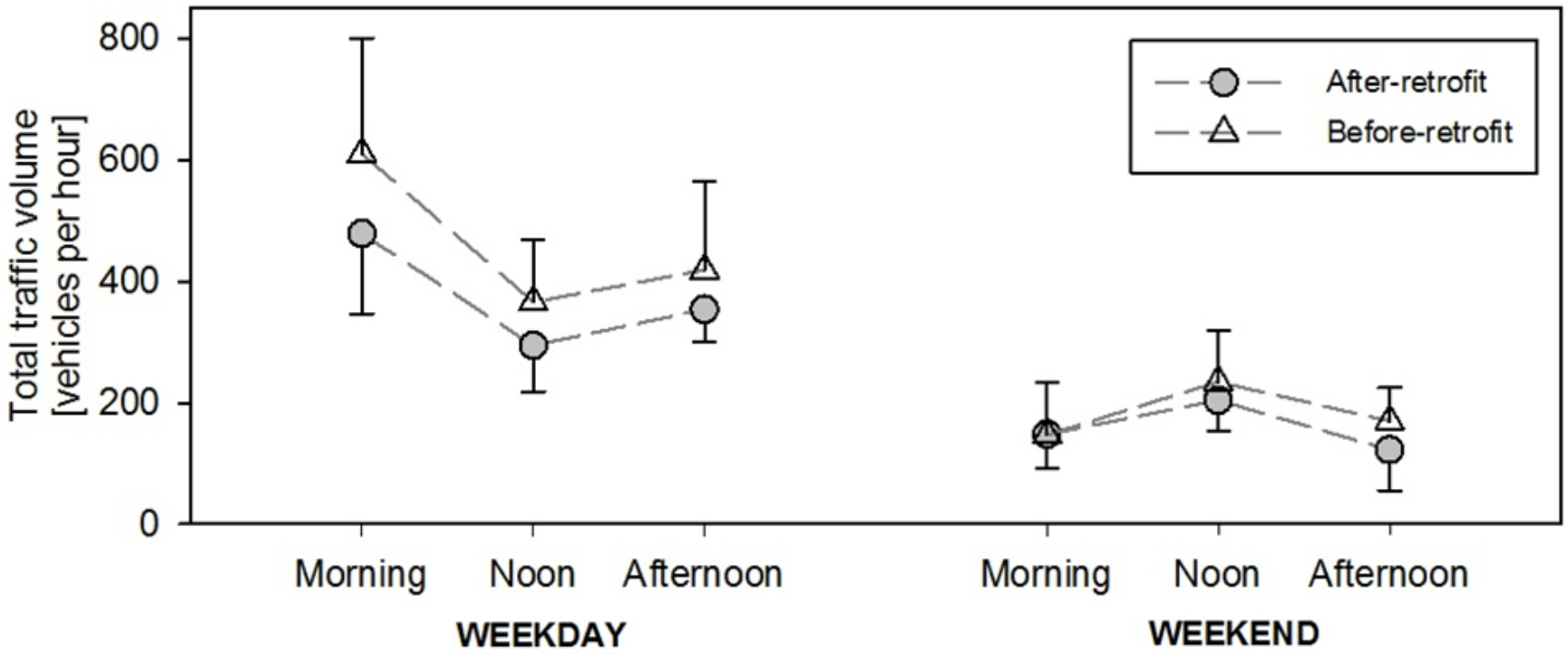


No significant change in $PM_{2.5}$, either way.

Results: Before-After Study

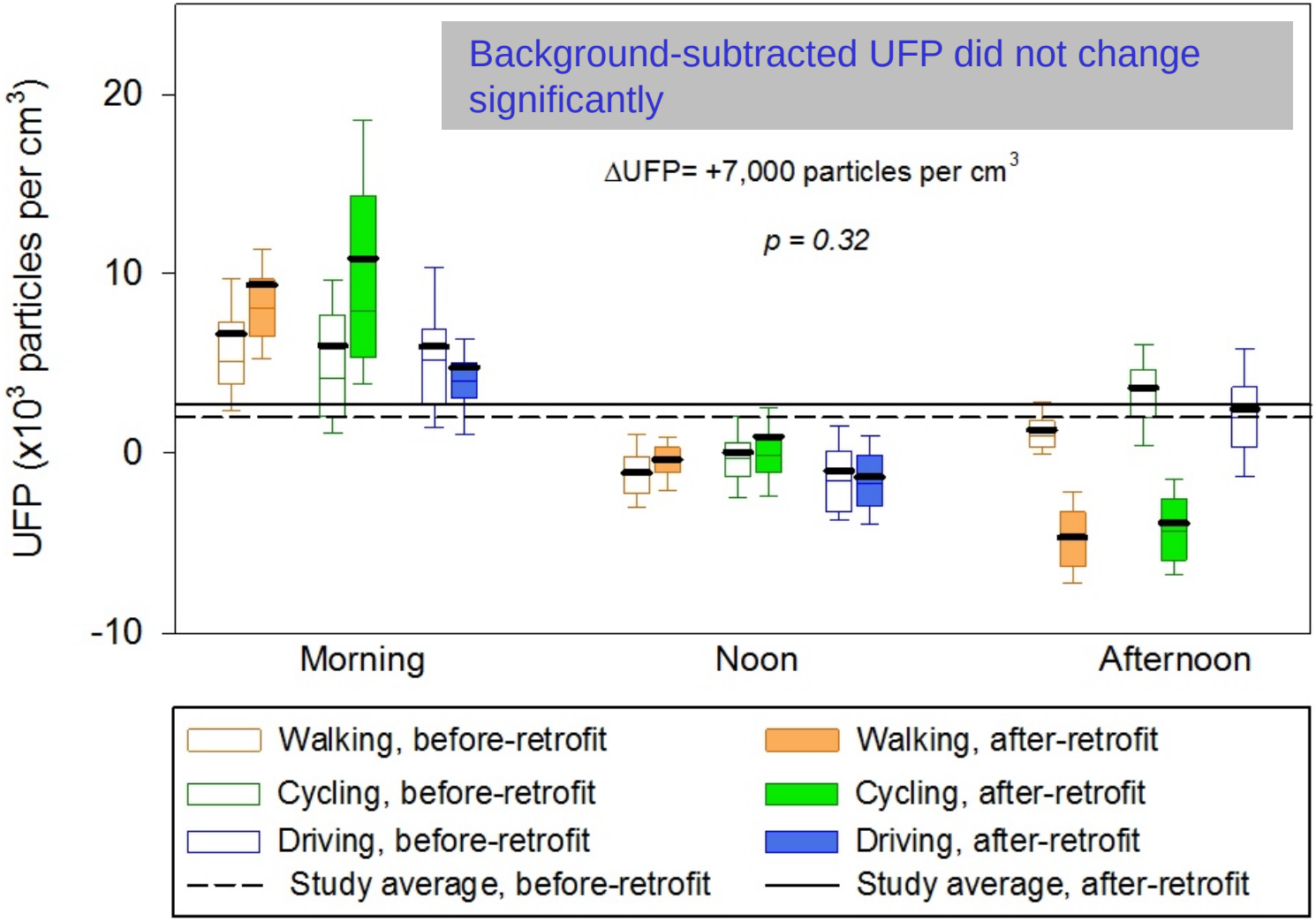
Site 2: MANGo

Overall decreased 16%, but not significant.

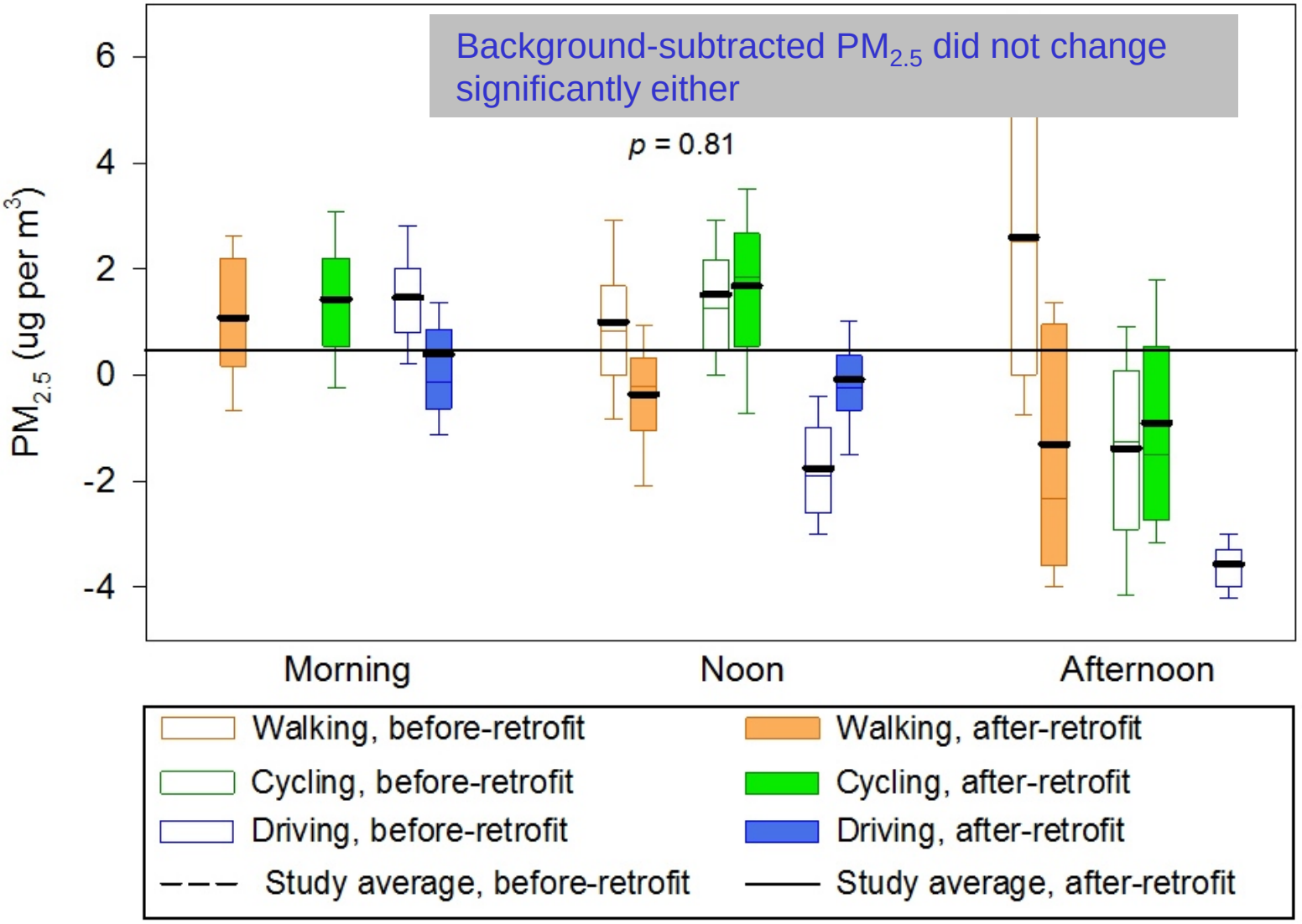


Results: Before-After Study

Site 2: MANGo



Results: Before-After Study



Results: Before-After Study

Site 2: MANGo

- MANGo survey
  - Before:
    - Valid response from 165 households
    - 27.5% response rate
  - After:
    - Valid response from 188 households
    - 31.3 % response rate

Results: Before-After Study

Site 2: MANGo

- MANGo survey on Travel behavior

- Examined three closely related factors

1) Most recent time of each type of travel
2) Frequency of each type of travel in the last seven days
3) Frequency of each type of travel in a typical week by commuters

Results: Before-After Study

Site 2: MANGo

- MANGo survey on Travel behavior
- Examined three closely related factors

1) Most recent time of each type of travel
   - project likely increased the frequency of using cycling and walking to access public transit
2) Frequency of each type of travel in the last seven days
3) Frequency of each type of travel in a typical week by commuters

Results: Before-After Study

Site 2: MANGo

- MANGo survey on Travel behavior
- Examined three closely related factors

1) Most recent time of each type of travel
2) Frequency of each type of travel in the last seven days
   - Project did NOT change local residents' use of transit, bicycle or walking for travel
   - But increased recreational biking
3) Frequency of each type of travel in a typical week by commuters

Results: Before-After Study

Site 2: MANGo

- MANGo survey on Travel behavior
- Examined three closely related factors

1) Most recent time of each type of travel
2) Frequency of each type of travel in the last seven days
3) Frequency of each type of travel in a typical week by commuters
   - MANGo project did NOT change the frequency of walking, biking, and driving or carpooling
   - MANGo project associated with negative effects of commuters' choice of transit - potentially due to off-site improvement in transit service along the Pico Blvd

Results: Before-After Study

Site 2: MANGo

- MANGo survey on Perceived barriers
  - Biking
    - ‘too busy’
    - ‘too many things to carry’
    - ‘too many cars in traffic’
    - ‘fast traffic’
    - ‘not enough bike lanes or wide curb lanes’
    - ‘unsafe street crossings’

Results: Before-After Study

Site 2: MANGo

- MANGo survey on Perceived barriers
  - Walking
    - ‘too busy’
    - ‘I simply do not like walking’

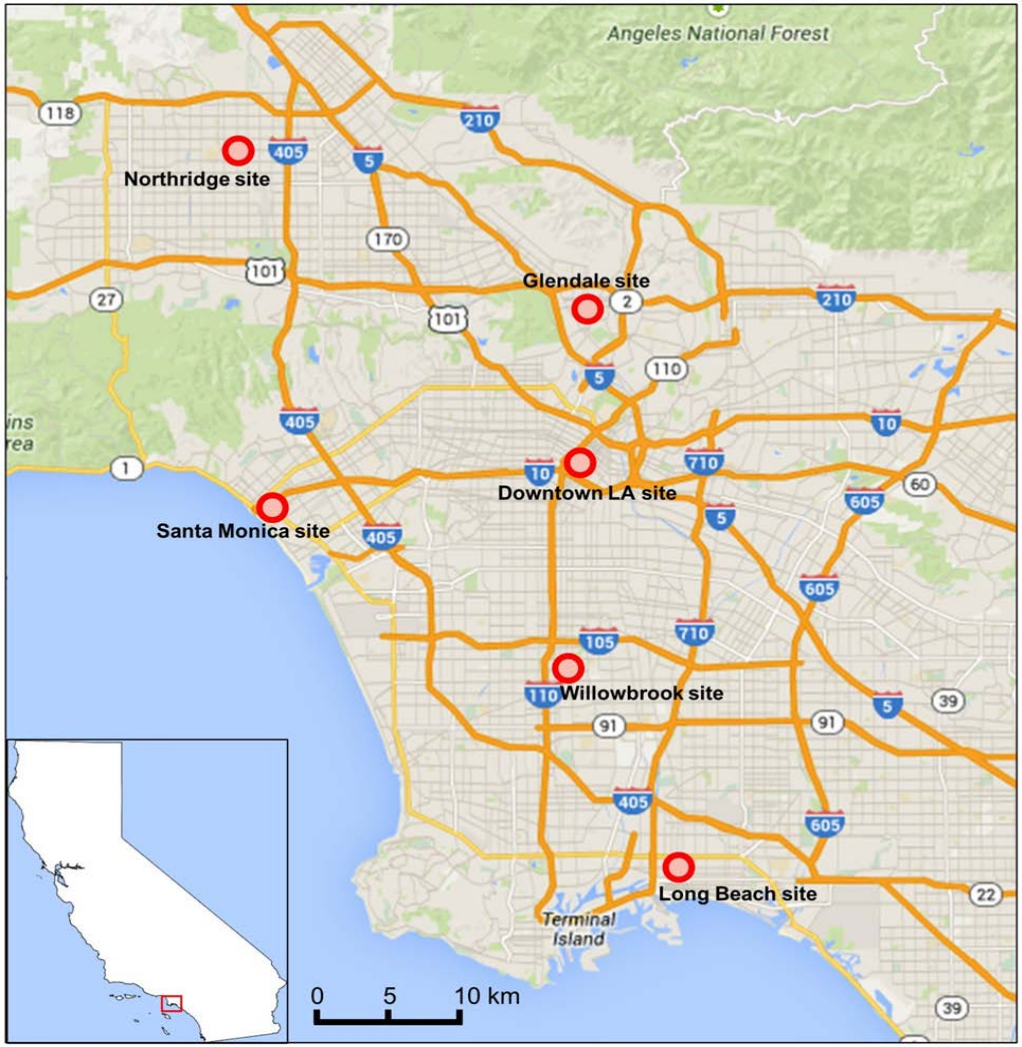
Results: Before-After Study

Site 2: MANGo

- MANGo survey on Perceived barriers
  - Taking transit
    - ‘transit does not accommodate my schedule’
    - ‘transit does not get me to where I want to go’
    - ‘transit vehicles are too slow’

Methods : DID Study

Locations of the six DID study sites



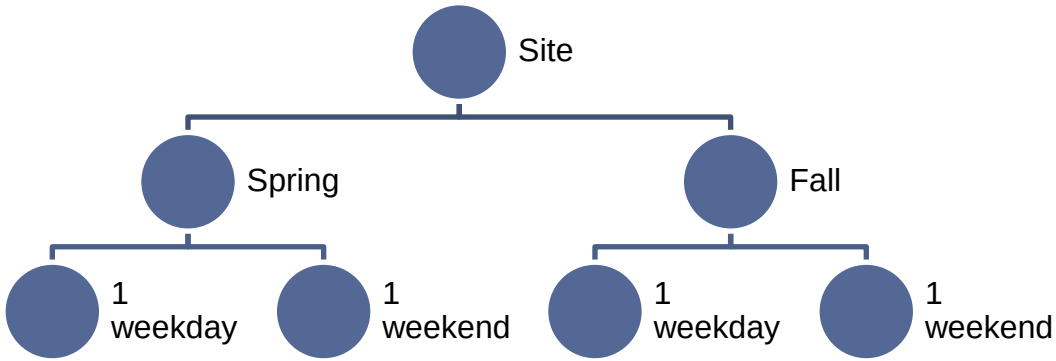
Methods : DID Study

Site	Location	Function	Complete Street	Incomplete Street
			St. Name (Num. of lanes)	St. Name (Num. of lanes)
Downtown LA	Downtown	Business	Spring (2)	Main (3)
Santa Monica	Downtown	Business	Sixth (4)	Fifth (4)
Long Beach	Urban	Mixed	Third (2)	Fourth (2)
Willowbrook	Suburban	Mixed	San Pedro (4)	Avalon (4)
Glendale	Suburban	Residential	Riverdale (2)	Vine (1)
Northridge	Suburban	Residential	Louise (4)	Hayvenhurst (4)

Methods : DID Study

Time frame

- **24 test days from October 2013 to March 2015**



x 6

- **Three two-hour sessions for each test day**

Morning **Noon** **Afternoon**

Methods : DID Study

Vehicular Traffic volume measurements

- Video footage & Manual counting
  - For the first 10 test days
  - Same as Before-After study

- Pneumatic tube counters
  - For the last 14 test days
  - 24-h continuous measurement

Methods : DID Study

On-road air quality measurements

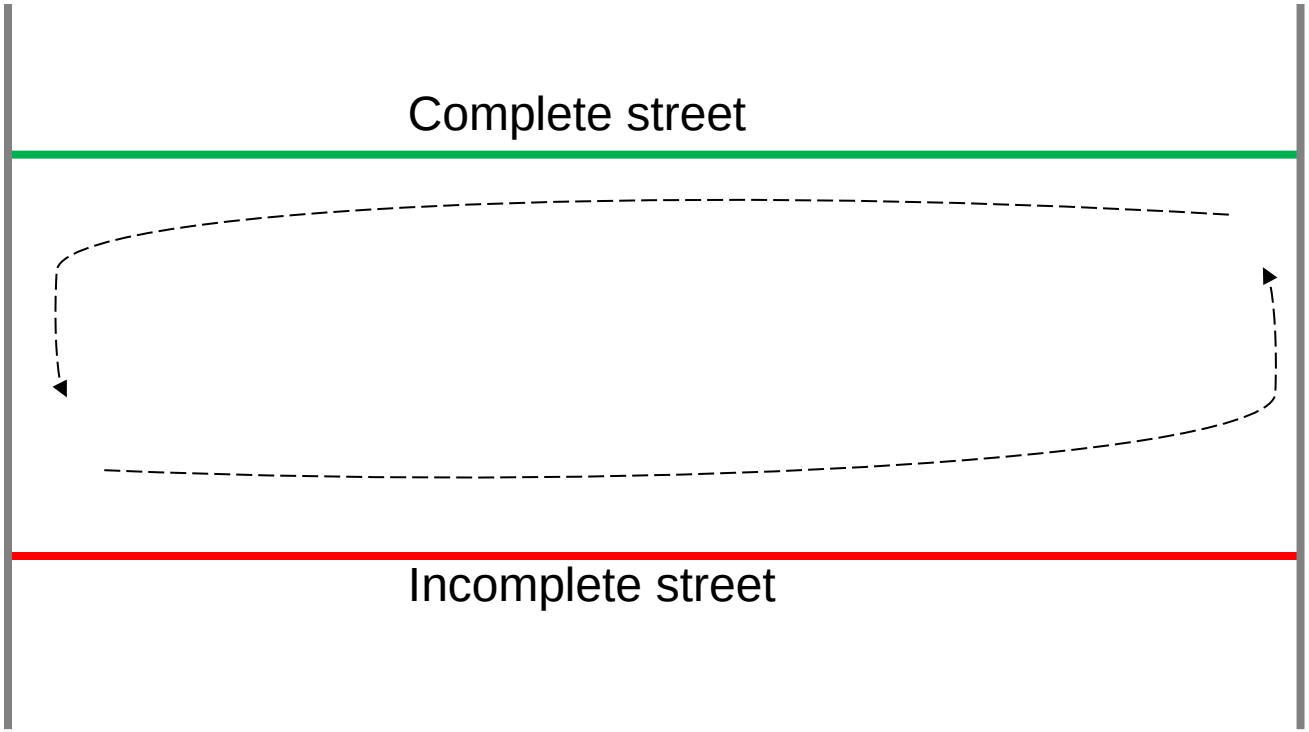
- Similar to Before-After Study
- Three modes
- Two sets of instruments

Walking Cycling Driving-with-windows-open

Methods : DID Study

On-road air quality measurements

- **Looping on twin-streets**



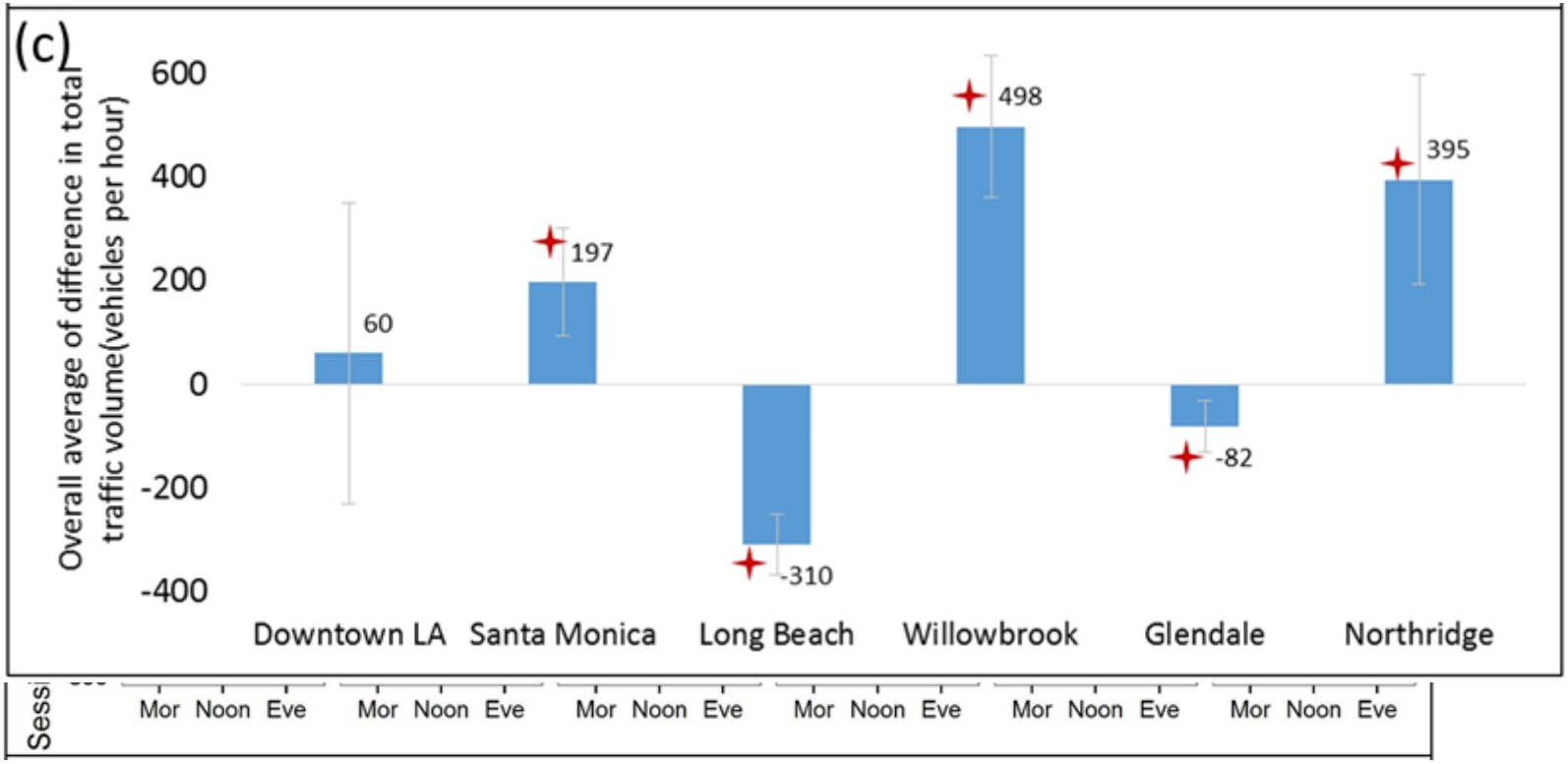
Methods : DID Study

Intercept survey

- One-page questionnaire
- Two surveyors on each street
- Placed at the middle of street
- Refusal counts recorded

Results : DID Study

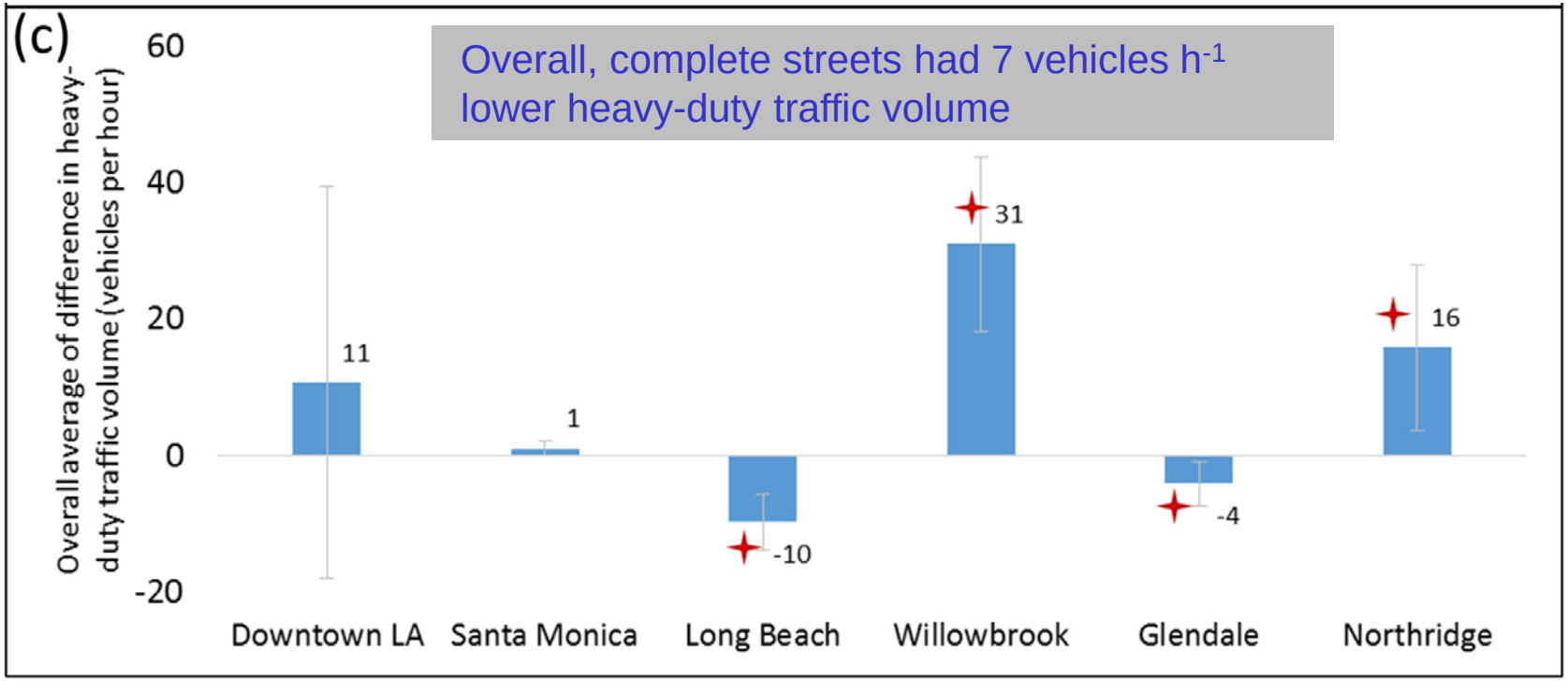
Total traffic volume



The positive values in panels (b) and (c) mean the incomplete street has higher total traffic volume. Overall, complete streets had 127 vehicles h^{-1} lower total traffic volume.

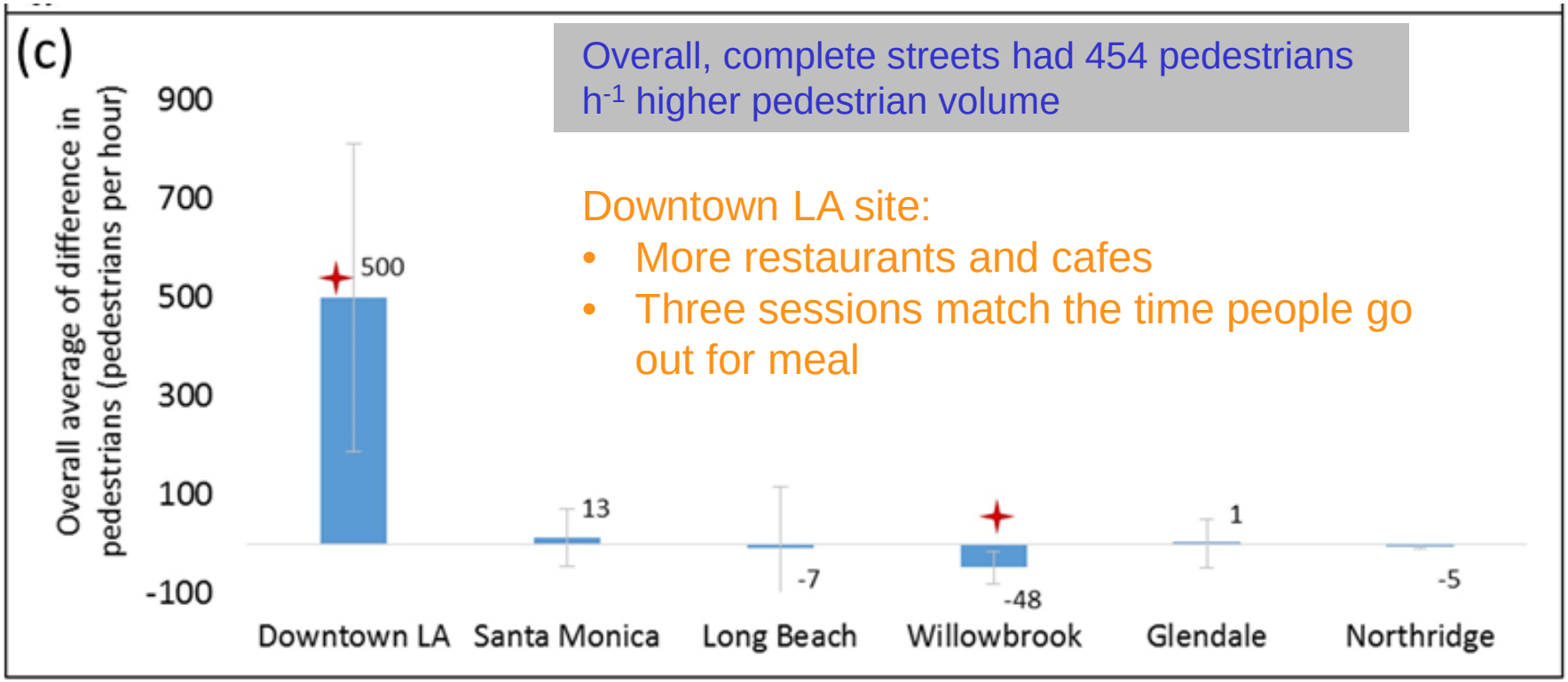
Results : DID Study

Heavy-duty traffic volume



Results : DID Study

Pedestrians volume



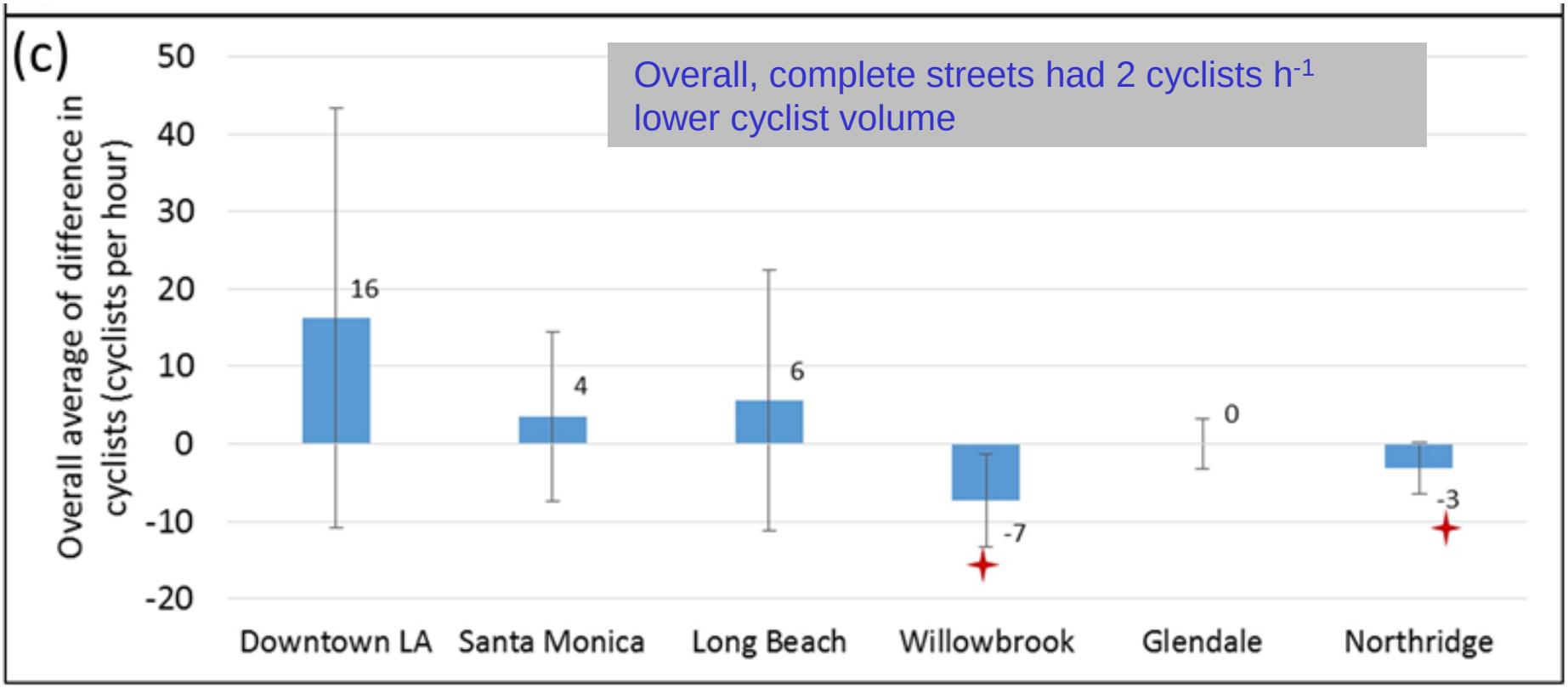
Overall, complete streets had 454 pedestrians h^{-1} higher pedestrian volume

Downtown LA site:

- More restaurants and cafes
- Three sessions match the time people go out for meal

Results : DID Study

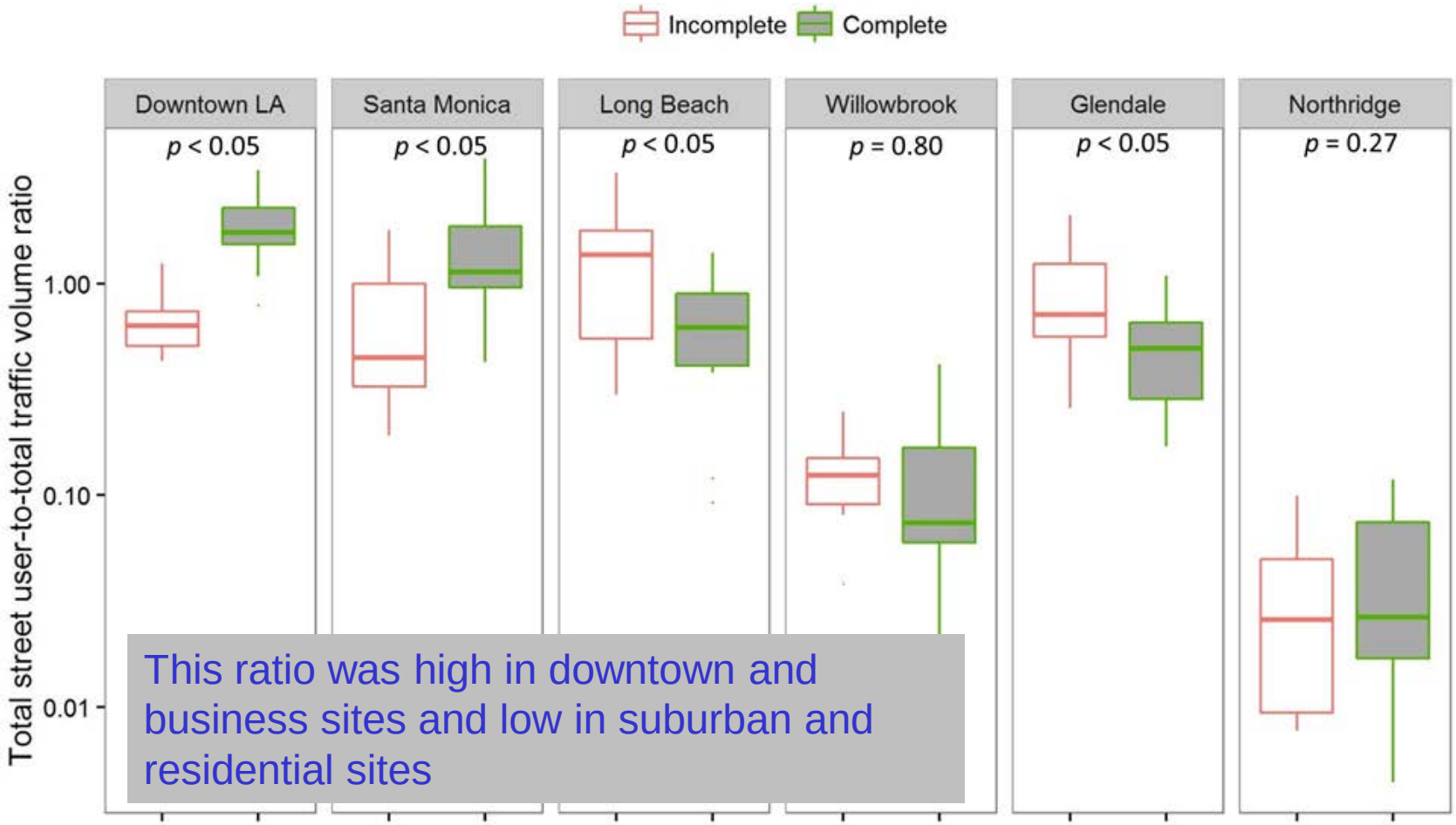
Cyclists volume



Overall, complete streets had 2 cyclists h^{-1} lower cyclist volume

Results : DID Study

Ratio between non-motorized street-user & vehicular traffic volume



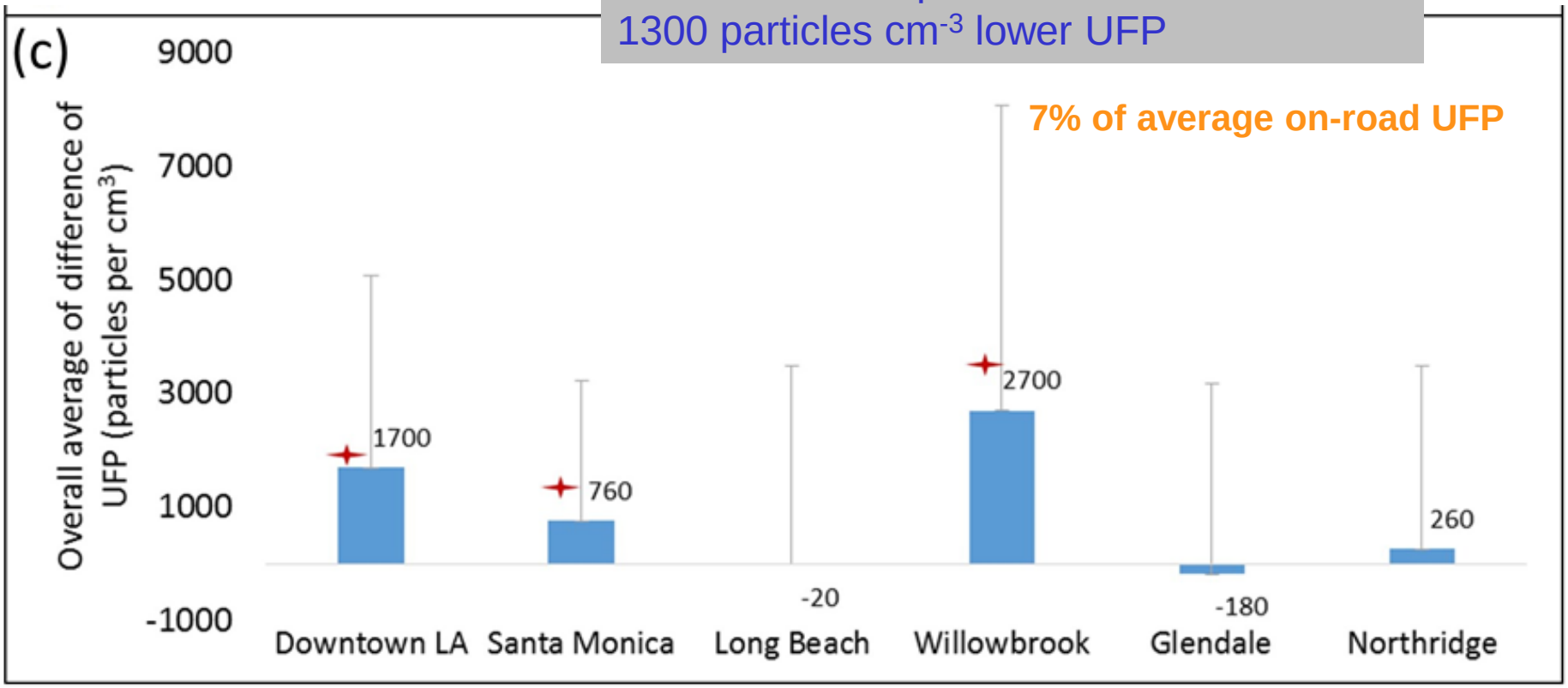
This ratio was high in downtown and business sites and low in suburban and residential sites

Results : DID Study

On-road air quality

- **UFP**

Overall, the complete streets had 1300 particles cm^{-3} lower UFP

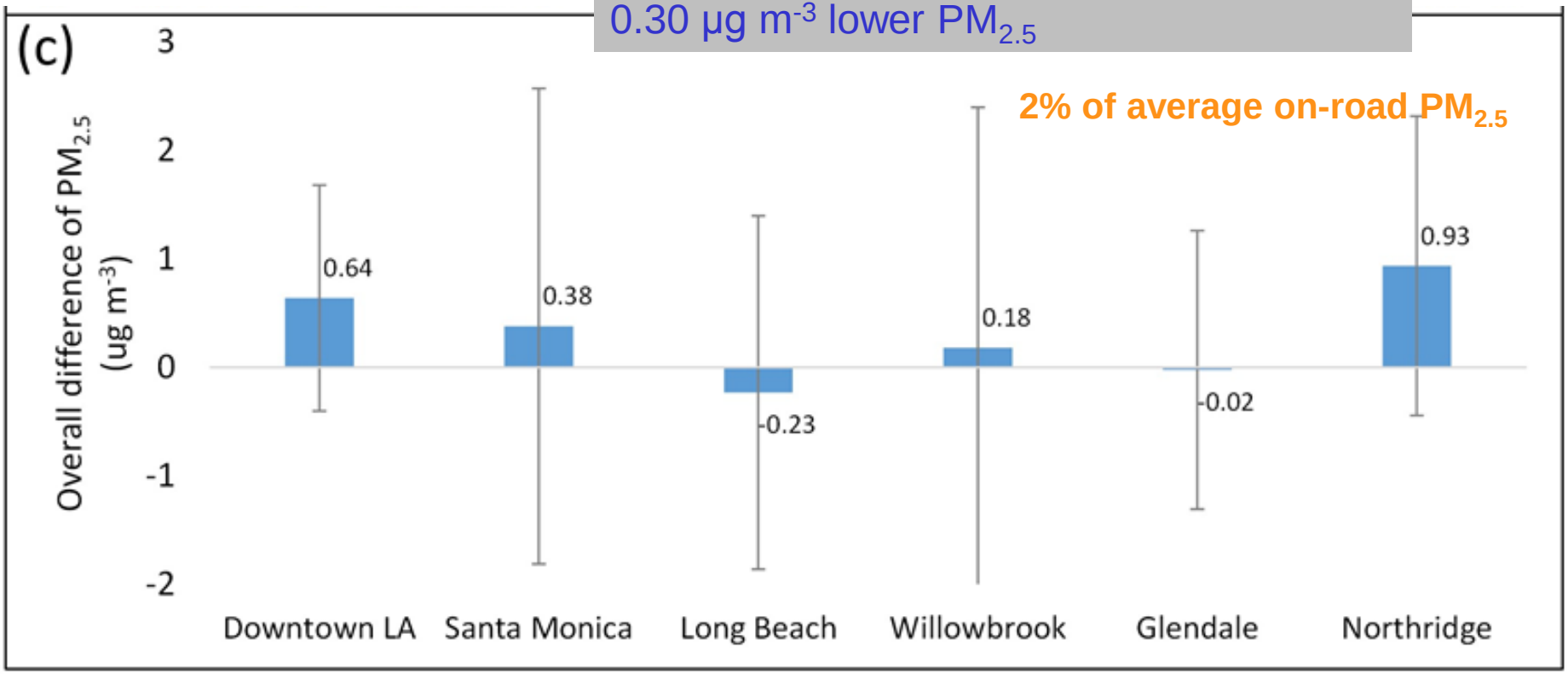


Results : DID Study

On-road air quality

- $PM_{2.5}$

Overall, the complete streets had 0.30 μg m^{-3} lower $PM_{2.5}$



Results : DID Study

Overview of results

Site	Location	Function	Difference between complete and incomplete street					
			UFP	$PM_{2.5}$	Total Traffic	Heavy-duty	Pedestrians	Cyclists
Downtown LA	Downtown	Business	-				+	
Santa Monica	Downtown	Business	-		-			
Long Beach	Urban	Mixed			+	+		
Willowbrook	Suburban	Mixed	-		-	-	-	-
Glendale	Suburban	Residential			+	+		
Northridge	Suburban	Residential			-	-		-

‘ + ‘ means significant higher values on complete street, and ‘ – ‘ means significant lower values on complete street.

Results : DID Study

Suburban and residential study sites had less forms collected because it is harder to find as many street-users

Intercept survey

- **Collected 774 complete survey forms**
- **714 refusals**

Site	Counts			Percentage		
	Complete Street	Incomplete Street	Total	Complete Street	Incomplete Street	Total
Downtown LA	149	113	262	35%	32%	34%
Santa Monica	98	85	183	23%	24%	24%
Long Beach	102	84	186	24%	24%	24%
Willowbrook	14	23	37	3%	6%	5%
Glendale	40	31	71	10%	9%	9%
Northridge	17	18	35	4%	5%	5%
Total	420	354	774	100%	100%	100%

Results : DID Study

Intercept survey

- **Collected 774 complete survey forms**
- **714 refusals**

	Street Type				Total	
	Complete		Incomplete			
	n	%	n	%	n	%
Men	255	61%	206	58%	461	60%
Women	165	39%	148	42%	313	40%
Total	420	100%	354	100%	774	100%

	Street Type					
	Complete		Incomplete		Total	
	n	%	n	%	n	%
White	150	36%	131	37%	281	36%
Latino/Hispanic	119	28%	82	23%	201	26%
African American	69	16%	47	13%	116	15%
Asian	41	10%	34	10%	75	10%
Mixed	20	5%	31	9%	51	7%
Native American	4	1%	8	2%	12	2%
Other	16	4%	20	6%	36	5%
Total	419	100%	353	100%	772	100%

Results : DID Study

Site	Street	Wide side walk	Intersection hard to cross	Too much traffic	Clean	Shade	Interesting things to do	Secure	Walk more
		Score of each question							
Downtown LA	Complete	2.54	3.70	2.58	3.414	1.95	1.67	2.16	2.28
	Incomplete	1.75	3.67	2.79	3.135	2.28	2.17	2.28	2.20
Santa Monica	Complete	1.73	4.03	3.20	1.520	1.43	2.02	1.52	2.02
	Incomplete	1.63	3.88	3.17	1.518	1.65	1.94	1.64	1.96
Long Beach	Complete	1.37	4.22	3.37	1.882	2.74	1.79	1.84	1.59
	Incomplete	1.75	3.78	3.52	1.607	2.79	1.99	2.20	2.01
Northridge	Complete	2.33	3.33	3.83	1.611	2.39	3.67	1.94	1.95
	Incomplete	1.47	3.35	3.47	1.647	1.47	3.29	1.12	2.61
					1.675	1.48	2.08	1.50	3.07
					2.097	2.71	3.32	1.81	2.22
					3.357	3.14	3.86	2.79	1.94
Willowbrook	Incomplete	2.70	2.78	2.96	3.739	3.74	3.43	3.00	1.71

Overall, street users believed that complete streets:
1) Had more shades
2) Had more interesting things to do
3) Were more secure to walk on
4) Had intersections easier to cross

Conclusions

- **Complete streets may have positive impacts on some (but not all) tested parameters**
  - **UFP, but not $PM_{2.5}$**
  - **Lower vehicular traffic volume, but not always**
  - **More pedestrians and cyclists, but not always**

- **Not all complete streets are created equal**

- **Complete streets can potentially reduce populations' exposure to traffic-related air pollutants**

Recommendations

- **Prioritize constructing complete streets projects in the downtown and business areas**
- **Long-term studies to further investigate the environmental and health impacts of complete streets**
  - **More metropolitan areas**
  - **Longitudinal survey and measurements**
- **More quantitative and objective measurements**
  - **e.g., drivers' perception on complete and incomplete streets**
- **Future retrofits be implemented in contiguous road network**

Acknowledgement

- **ARB contract number 11-312**
- **UCLA research staff and students**
  - David Fung
  - Shi Shu
  - Eon Lee
  - Pu Yang
  - Fei Li
  - Tongke Zhao
  - Yan Lin
  - Nu Yu
  - Claire Kim
  - Shihao Zhu
  - Elamar Moully
  - Mark Rayos
  - Gurdeep Kaur
  - Charlene Nguyen
  - Sherry Lin

Publications

- **Shi Shu, David C. Quiros, Rui Wang, and Yifang Zhu "Changes of street use and on-road air quality before and after complete street retrofit: An exploratory case study in Santa Monica, California" 2014, *Transportation Research Part D: Transport and Environment for publication*, 32: 387–396.**

- **David Quiros, Eon Lee, Rui Wang, and Yifang Zhu "Ultrafine particle exposures while walking, cycling, and driving along an urban residential roadway", 2013, *Atmospheric Environment.* 73: 185-194.**

Disclaimer

The statements and conclusions in this Report are those of the contractor and not necessarily those of the California Air Resources Board (ARB). The mention of commercial products, their source, or their use in connection with material reported herein is not to be construed as actual or implied endorsement of such products.

Thank you!