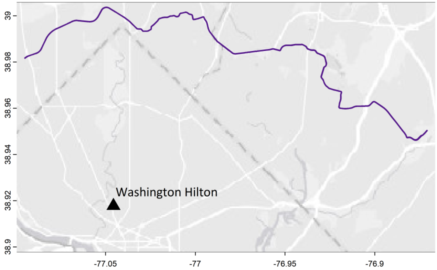
Can Light Rails Provide the Track to Cleaner Air?

T. Ruangmas*, L. Thomas, R. Yance, G. Zhang

University of Maryland

Motivation

The purple line, a new light rail system north of DC, is scheduled to open in late 2027.



Have past light rail openings lead to a decrease in air pollution?

What are Light Rails?

- Light Rails are electric-powered vehicles on dedicated tracks.
- They usually run alongside roads, with dedicated rights-of-way.

Light Rails vs. Subways

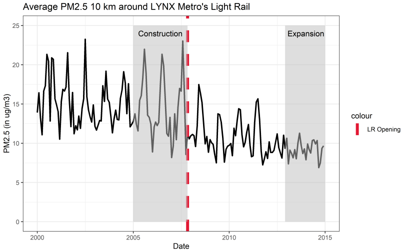
- Light rails have a lower passenger capacity.
- Light rails make more frequent stops.
- Light rails are much cheaper to build.

Literature Review

- Existing studies have found that **subway** systems are effective in reducing air pollution.
  - Chen & Whalley (2012) found that Taipei's Metro System opening reduced CO by 5 to 15 percent.
  - Gendron-Carrier et al. (2022) found that among 58 subway openings globally, only those in highly polluted cities see a 4 percent reduction.
  - Xie et al. (2024) found that 15 subway openings in China reduced PM2.5 by 19 percent.
- Fageda (2021) is the only study that used a quasi-experimental research design to estimate the impact of **light rail** openings across 98 European cities and found a slight reduction of 3 percent.

Hypothesis

- Light rail openings in the US will cause a substitution between people driving their own cars or taking buses to use the light rail, reducing air pollution.
- We expect to see a smaller decrease than 3 percent as:
  - The US population drives more cars than Europe.
  - We removed data from the light rail construction period, which can increase pollution before the light rail opening.

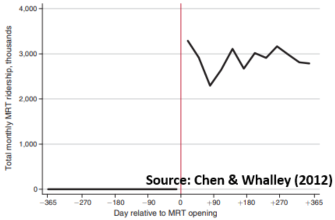


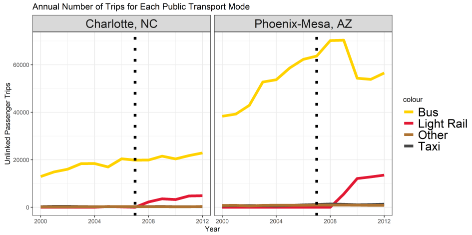
Data

- Daily PM2.5, from 2000 to 2016, with 1 km x 1 km grid resolution from Di et al. (2019).
- 47 land surface meteorological variables with 25 km x 25 km grid resolution from NASA GLDAS 2.
- Treated city selection criteria
  - The light rail construction period must start a few years after 2000.
  - Buses were the primary public transit mode before the light rail opened.
- These criteria narrows down to two light rail systems:
  - **Charlotte, NC's LYNX system**, which opened in 2007
  - **Phoenix, AZ's Valley Metro Rail system**, which opened in 2008

Research Design

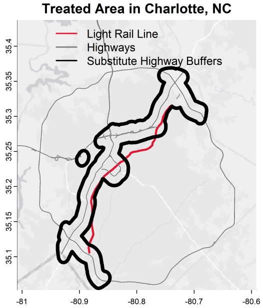
- Previous studies on the subway's impact on air pollution (Chen and Whalley, 2012; Gendron-Carrier et al., 2022; Xie et al., 2024) used Discontinuity-Based OLS as there was instant uptake in ridership.
- We will use **difference-in-difference** as light rail ridership gradually increases in treated cities.

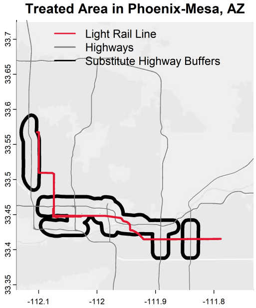




Treated Area

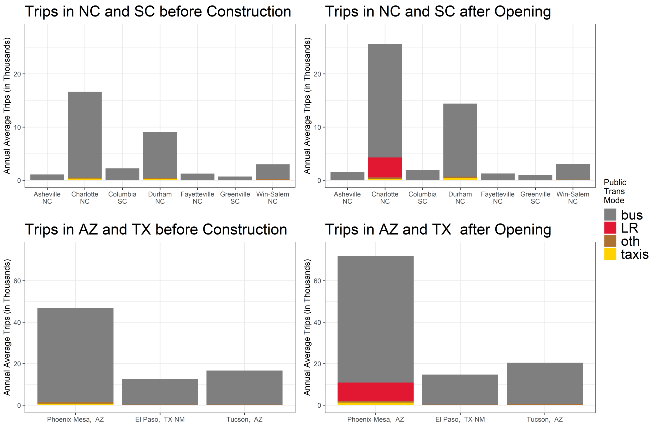
- We indicate potential highways where the light rails are substitutes and draw 1.5 km buffers around each highway.
- We then find the average daily PM2.5 and meteorological variables within those areas.





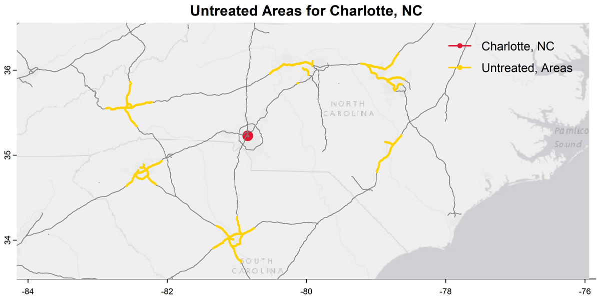
Untreated Area

- For each treated city, we select untreated cities with no light rails and no subways but similar shares of buses and taxis.

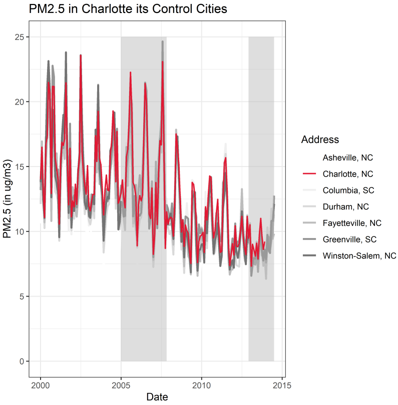


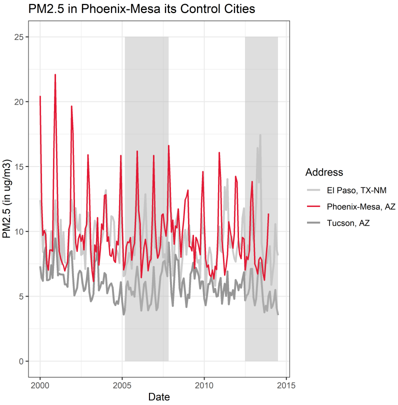
Untreated Area

- For each untreated city, we crop interstates within a 30 km radius of each city and create 1 km buffers around each cropped interstate.
- We find the daily average PM2.5 and meteorology values within each city's interstate buffers.



Parallel Trends





DiD Specification

First, we ran regressions separately for Charlotte, NC and its control cities, and Phoenix-Mesa, AZ and its control cities. Our regression specification is:

$$P_{it} = \gamma(D_i \times Operating_t) + W_{it}'\beta + \alpha_i + \mu_{it} + \kappa_t + \epsilon it$$

- where P_{it} are PM2.5 levels (in ug/m3) for each city i and day t.
- D_i is a dummy variable that is equal to one when city i is the city with a light rail system.
- $Operating_t = 1$ when the light rail system in the treated city has opened and $Operating_t = 0$ before construction.
- W_{it} includes 47 meteorological control variables.
- α_i are city fixed effects. μ_{it} are day of week-city fixed effects.
- κ_t are month fixed effects.

DiD Results for Two Cities Separately

Dependent Variable:	PM2.5					
Treated City	Charlotte, NC			Phoenix-Mesa, AZ		
Model:	(1)	(2)	(3)	(4)	(5)	(6)
operating	-4.1***	-4.2***	-4.1***	-0.42***	-0.48**	-0.43***
	(0.23)	(0.23)	(0.23)	(0.02)	(0.09)	(0.02)
operating × treatcity	-0.28	-0.28	-0.28	-0.39**	-0.39**	-0.39**
	(0.24)	(0.24)	(0.24)	(0.08)	(0.07)	(0.08)
Fixed-effects						
day of week-month	Yes			Yes		
city	Yes	Yes	Yes	Yes	Yes	Yes
day of week-city		Yes	Yes		Yes	Yes
month			Yes			Yes
Observations	26,194	26,194	26,194	9,867	9,867	9,867
Adjusted R^2	0.34	0.32	0.33	0.32	0.29	0.32

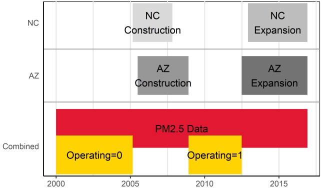
Clustered (city) standard-errors in parentheses
*Signif. Codes: ***: 0.01, **: 0.05, *: 0.1*

DiD Results for Two Cities Separately

Dependent Variable:	PM2.5	
Treated City	Charlotte, NC	Phoenix-Mesa, AZ
operating × Monday	-4.0*** (0.25)	-0.27* (0.09)
operating × Tuesday	-3.8*** (0.25)	-0.45 (0.20)
operating × Wednesday	-4.6*** (0.23)	-0.63*** (0.03)
operating × Thursday	-4.2*** (0.21)	-0.72*** (0.02)
operating × Friday	-4.1*** (0.20)	-0.57* (0.17)
operating × Saturday	-4.1*** (0.31)	-0.24 (0.16)
operating × Sunday	-3.8*** (0.25)	-0.11** (0.02)
operating × treatcity × Monday	0.03 (0.26)	-0.97** (0.14)
operating × treatcity × Tuesday	-0.35 (0.25)	-0.69* (0.23)
operating × treatcity × Wednesday	-0.62** (0.25)	-0.63** (0.08)
operating × treatcity × Thursday	-0.51* (0.24)	-0.32* (0.08)
operating × treatcity × Friday	-0.28 (0.21)	-0.10 (0.15)
operating × treatcity × Saturday	-0.16 (0.32)	-0.09 (0.12)
operating × treatcity × Sunday	-0.09 (0.28)	0.11 (0.08)
day of week-city	Yes	Yes
city	Yes	Yes
month	Yes	Yes
Observations	26,194	9,867
Adjusted R^2	0.33	0.32

Clustered (city) standard-errors in parentheses
*Signif. Codes: ***: 0.01, **: 0.05, *: 0.1*

DiD with Two Treated Cities Combined



Dependent Variable:	PM2.5		
Model:	(1)	(2)	(3)
operating	-3.4***	-3.5***	-3.4***
	(0.60)	(0.62)	(0.59)
operating × treatcity	0.65	0.67	0.65
	(1.5)	(1.5)	(1.5)
Fixed-effects			
day of week-month	Yes		
day of week-city		Yes	Yes
city	Yes	Yes	Yes
month			Yes
Observations	31,670	31,670	31,670
Adjusted R^2	0.36	0.35	0.36

Clustered (city) standard-errors in parentheses
*Signif. Codes: ***: 0.01, **: 0.05, *: 0.1*

DiD with Two Treated Cities, Each Day of the Week

Dependent Variable:	PM2.5
operating × Monday	-3.3*** (0.60)
operating × Tuesday	-3.2*** (0.55)
operating × Wednesday	-3.8*** (0.64)
operating × Thursday	-3.6*** (0.55)
operating × Friday	-3.5*** (0.59)
operating × Saturday	-3.5*** (0.67)
operating × Sunday	-3.2*** (0.60)
operating × treatcity × Monday	0.53 (1.1)
operating × treatcity × Tuesday	0.41 (1.3)
operating × treatcity × Wednesday	0.47 (1.6)
operating × treatcity × Thursday	0.46 (1.5)
operating × treatcity × Friday	0.81 (1.5)
operating × treatcity × Saturday	0.94 (1.6)
operating × treatcity × Sunday	0.89 (1.6)
Fixed-effects	
day of week-city	Yes
city	Yes
month	Yes
Observations	31,670
Adjusted R^2	0.36

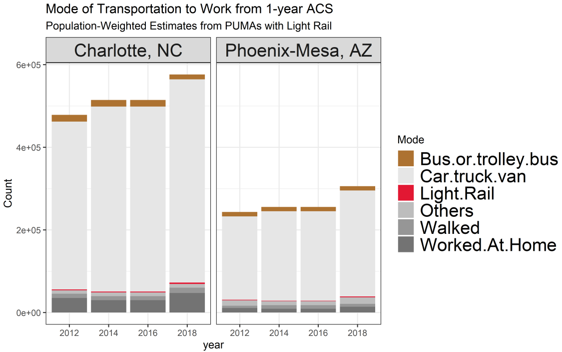
Clustered (city) standard-errors in parentheses
*Signif. Codes: ***: 0.01, **: 0.05, *: 0.1*

Conclusion

- Although we found reductions on weekdays when analyzing the two cities separately, we did not see the same results when all our data were combined.
- Factors that may confound our results are changes in the attainment status of the treated counties:
  - Maricopa County, where Phoenix is, no longer had a non-attainment status for 1-hour O3 and CO from 2005.
  - Mecklenburg County, where Charlotte is, had non-attainment for 8-hour O3 starting in 2004.

Conclusion

- Our results confirm findings from Duranton and Turner (2011) that changes in the provision of public transportation do not impact vehicle kilometers traveled.
- The American Community Surveys showed that very few people above 16 used the light rail to commute to work.



Future Work

- Our standard errors may be underestimated because we only have 10 cities and 10 clusters.
  - We are exploring using synthetic control to recalculate the impacts or
  - Increase the number of treated cities by including Minneapolis, MN, and Houston, TX. However, light rail construction in those cities began mid-2001, making our pre-treatment period very small.