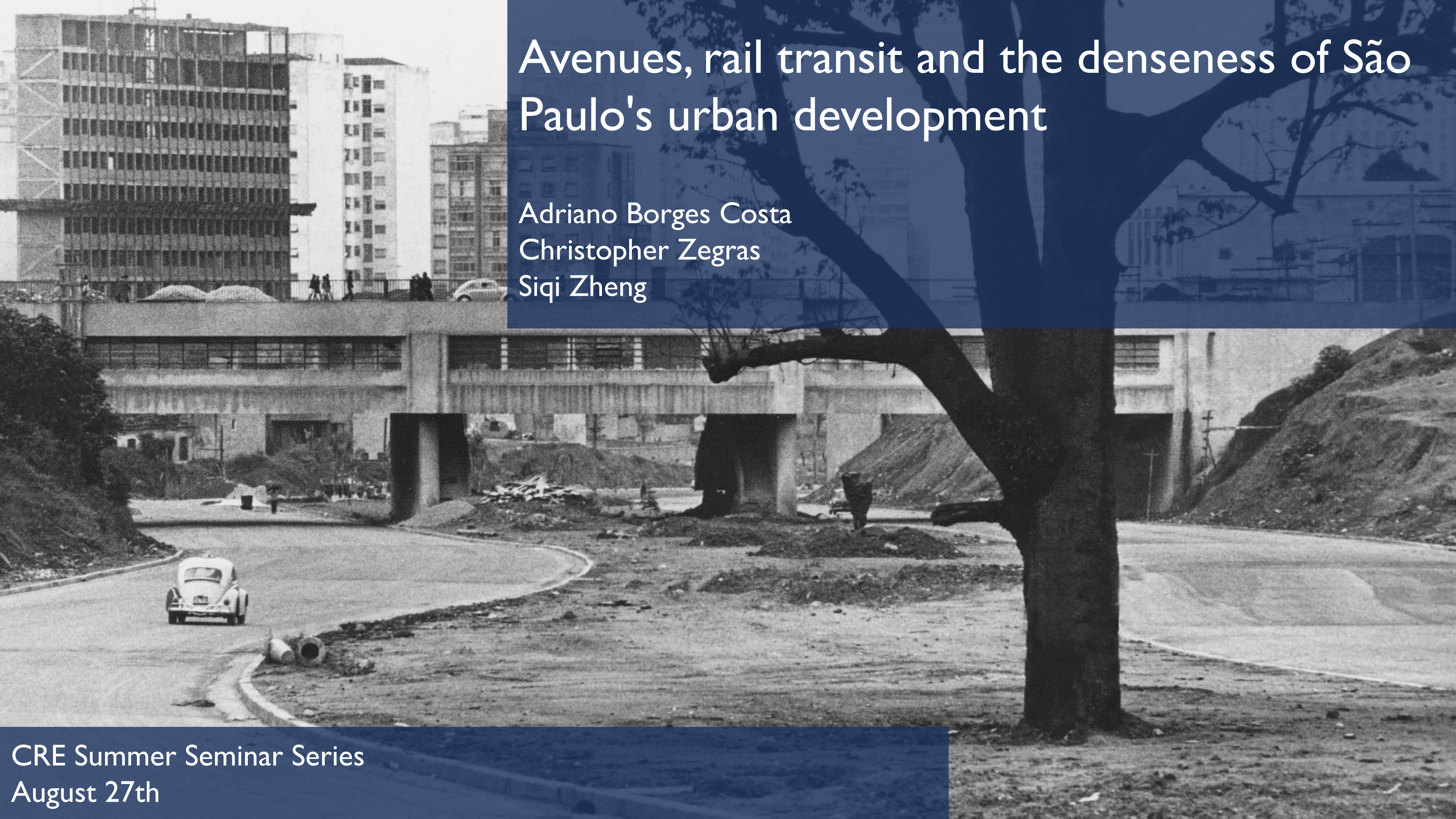

Avenues, rail transit and the denseness of São Paulo's urban development

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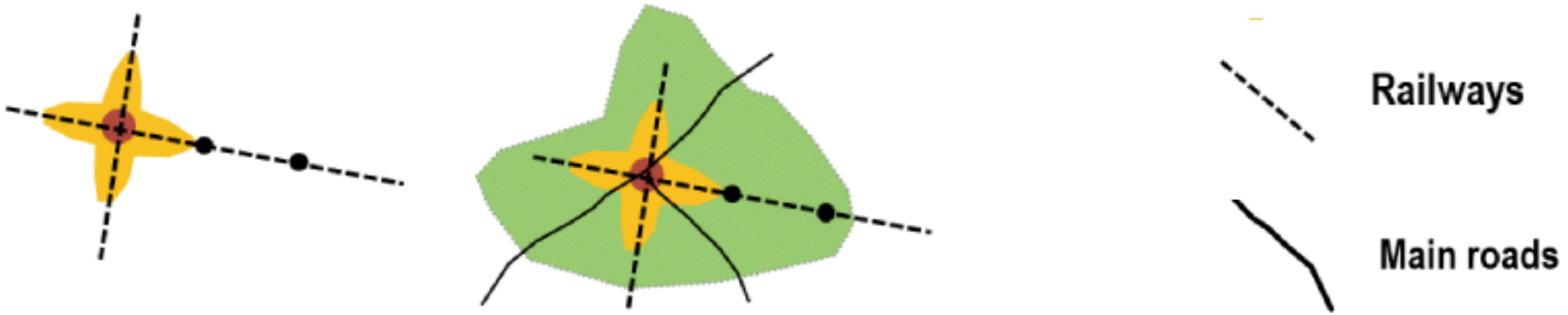
Christopher Zegras
Siqi Zheng

CRE Summer Seminar Series
August 27th

- Causal inference on how investments in road transportation infrastructure and rail transit impacted the vertical and horizontal urban development of the city of São Paulo (Brazil)
  - Construction of avenues crossing the urbanized area to connect suburban and peripheral neighborhoods generated urban expansion
  - Investments in rail transit promoted vertical neighborhoods with a higher building density.
- Idiosyncrasies of São Paulo's transportation development offered us the opportunity to use urban river courses and abandoned streetcars lines to instrument for the arterial road and transit network expansion

- The paper innovates in three aspects:
  - develop an innovative historical instrumental variable using urban river courses and abandoned streetcars lines
  - differentiate the impacts of urban roads and rail transit
  - differentiate vertical or horizontal urban development.
- Contributes to the literature on the interaction between transportation and land use
  - Nathaniel Baum-Snow's papers in the North-American and Chinese context are the most closely related analysis, as they investigate the impact of transport infrastructure from an intra-city perspective.
  - Evidence on highways promoting suburbanization
  - This paper is the first to investigate how urban road transportation and rail transit constructions differently contribute to horizontal and vertical urban expansion with a research design identifying causal effects

FRAMEWORK

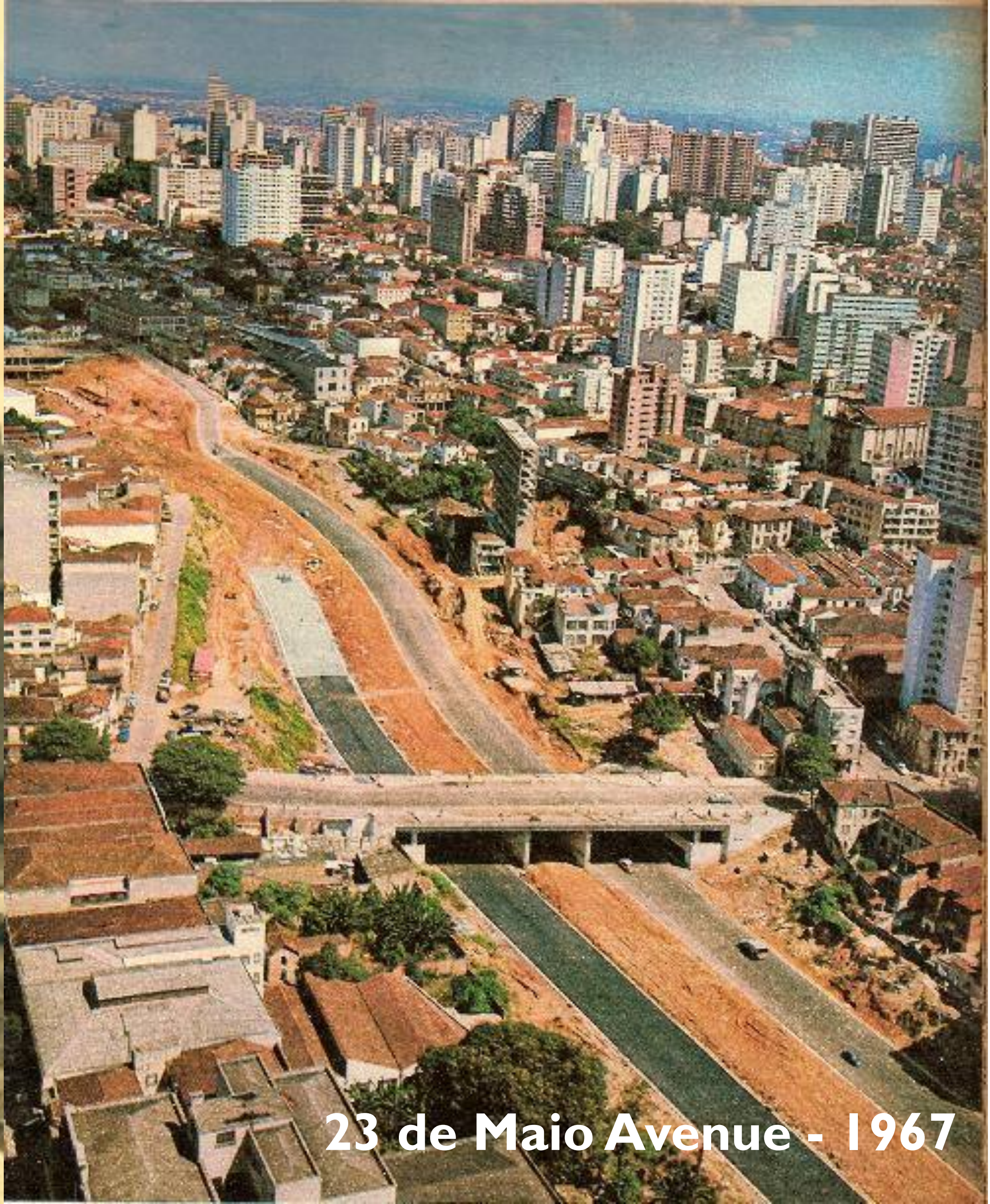


- Mass transit is more dependent on density and ridership demand
- Transit accessibility: concentrated and intense (around the stations) and decreases quickly with distance as it does not reach the last mile
- Roads accessibility: dispersed and less intense gains, not limited to the bordering areas of the access points, as it does not have the last mile problem


Teodoro Sampaio Street - 1904


Libero Badaró Street - 1919

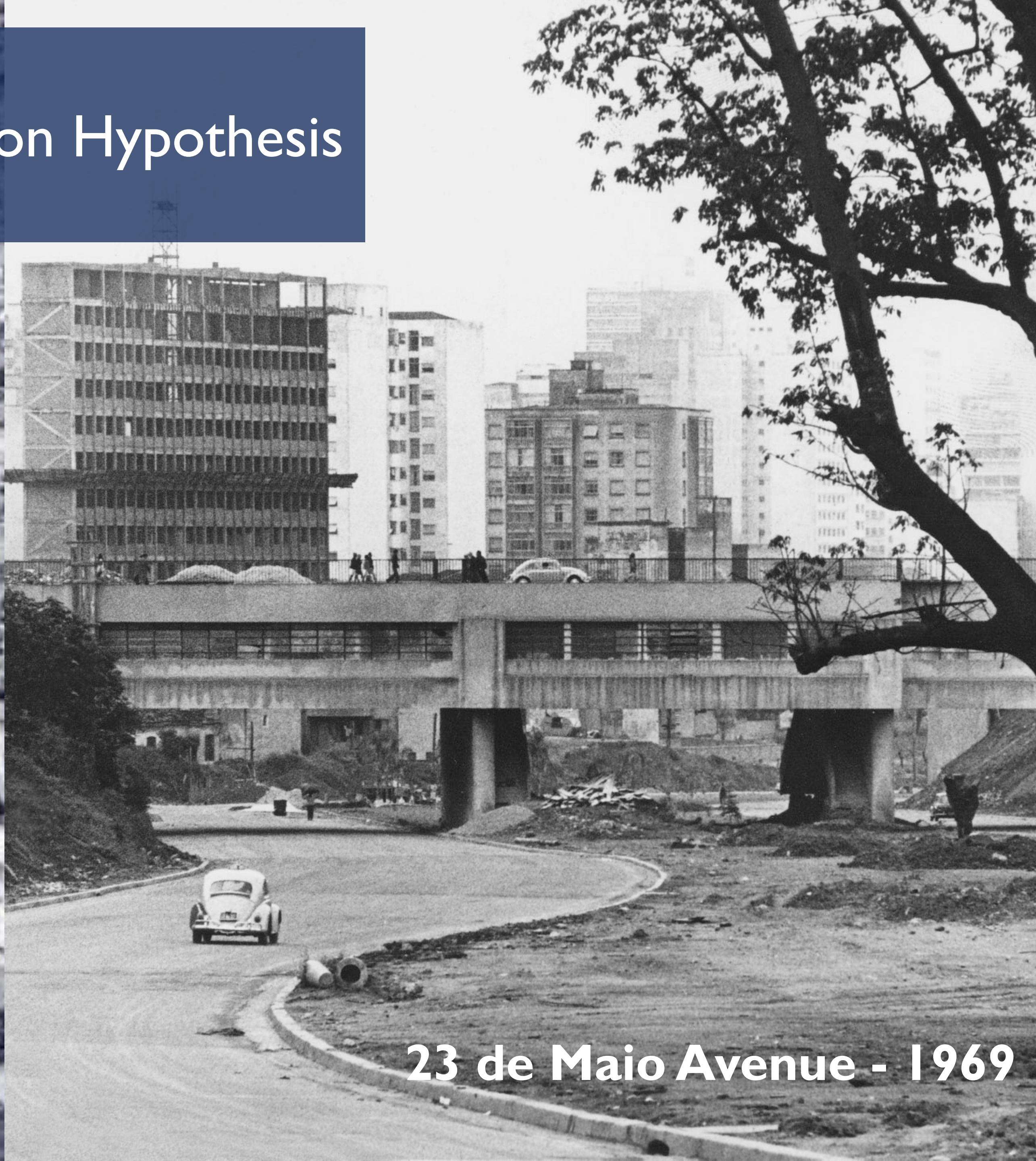
Pompeia Avenue - 1922



23 de Maio Avenue - 1967

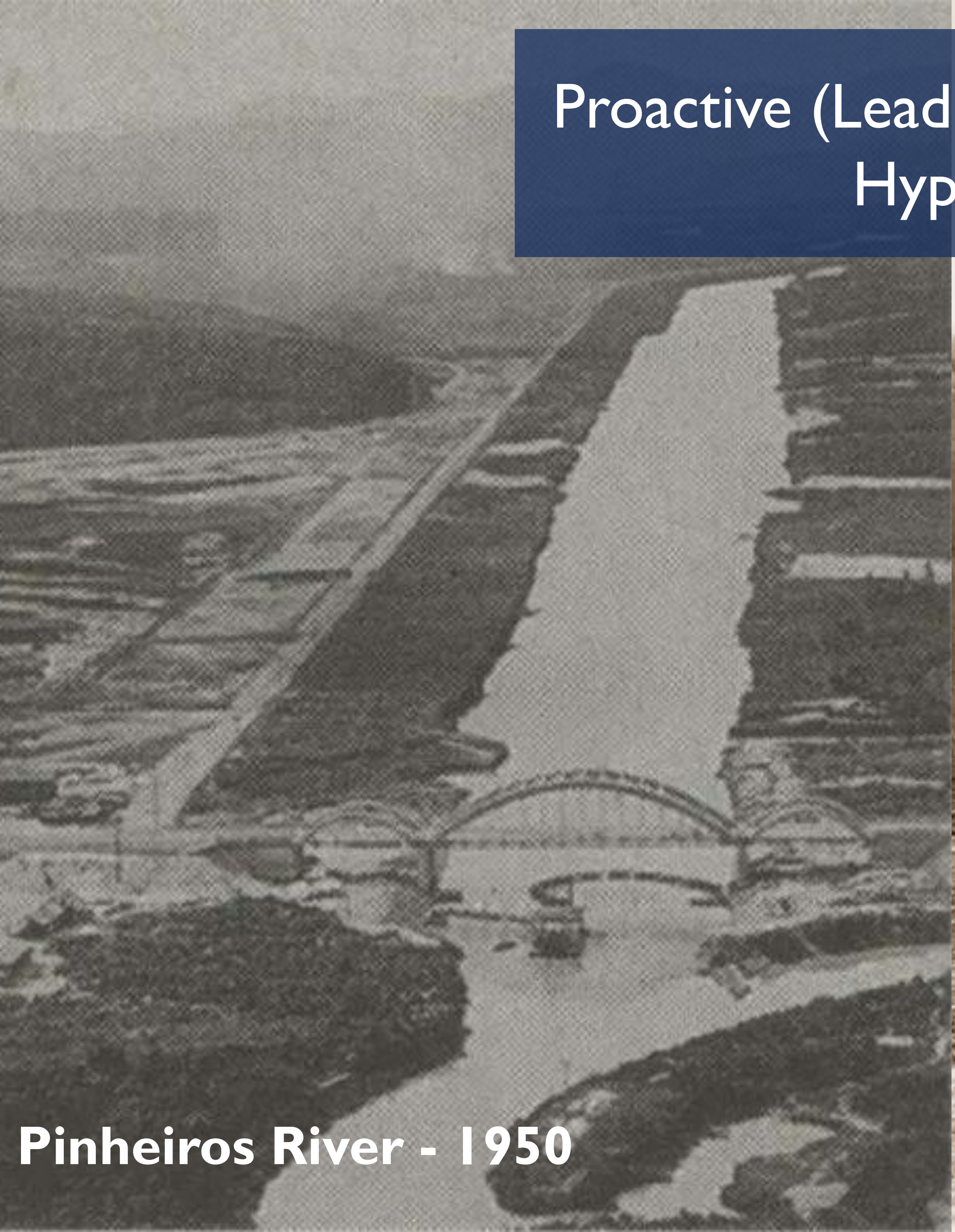
Reactive Transportation Hypothesis

Jabaquara Avenue - 1972



23 de Maio Avenue - 1969

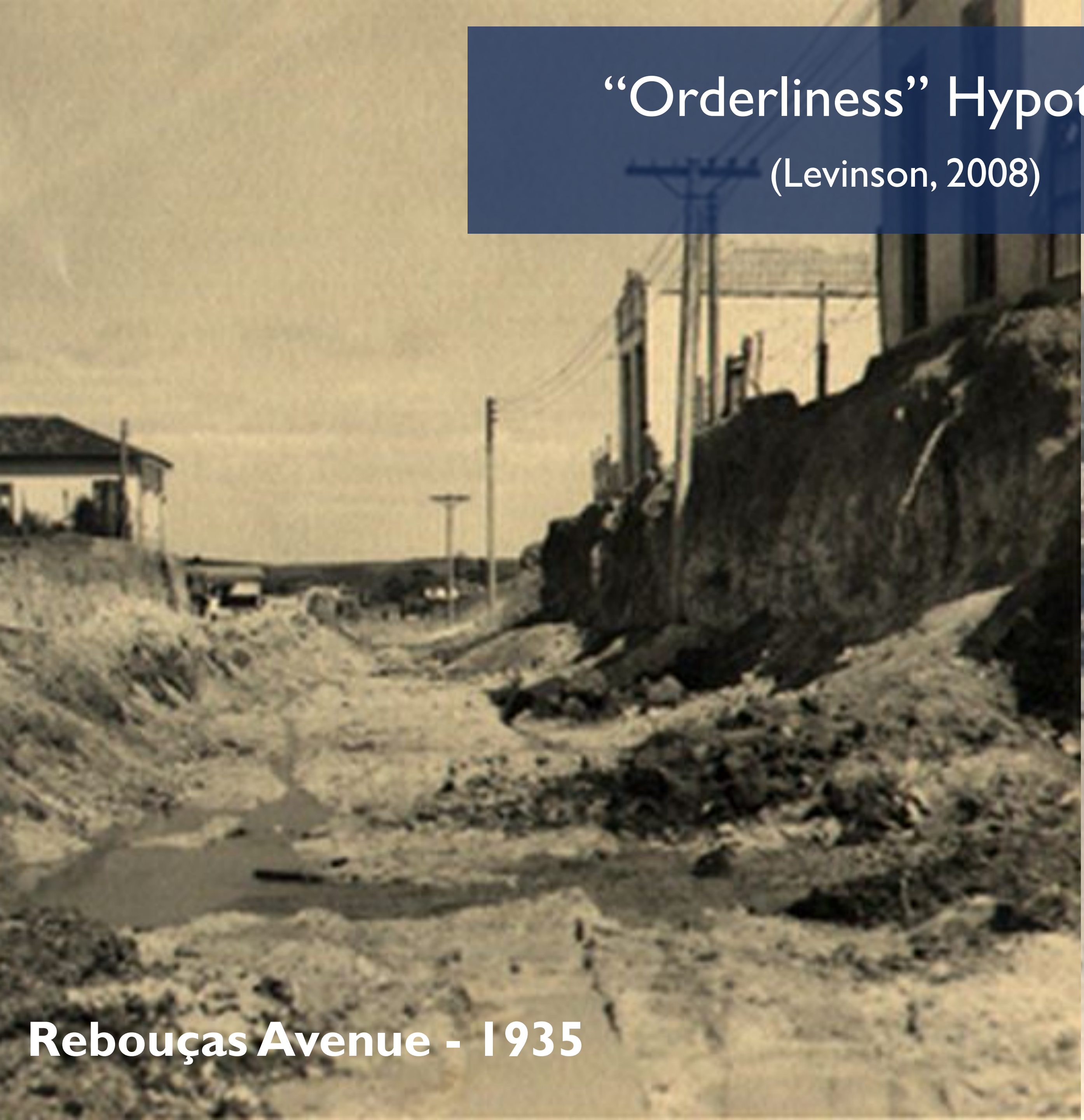
Proactive (Leading) Transportation Hypothesis


Pinheiros River - 1950

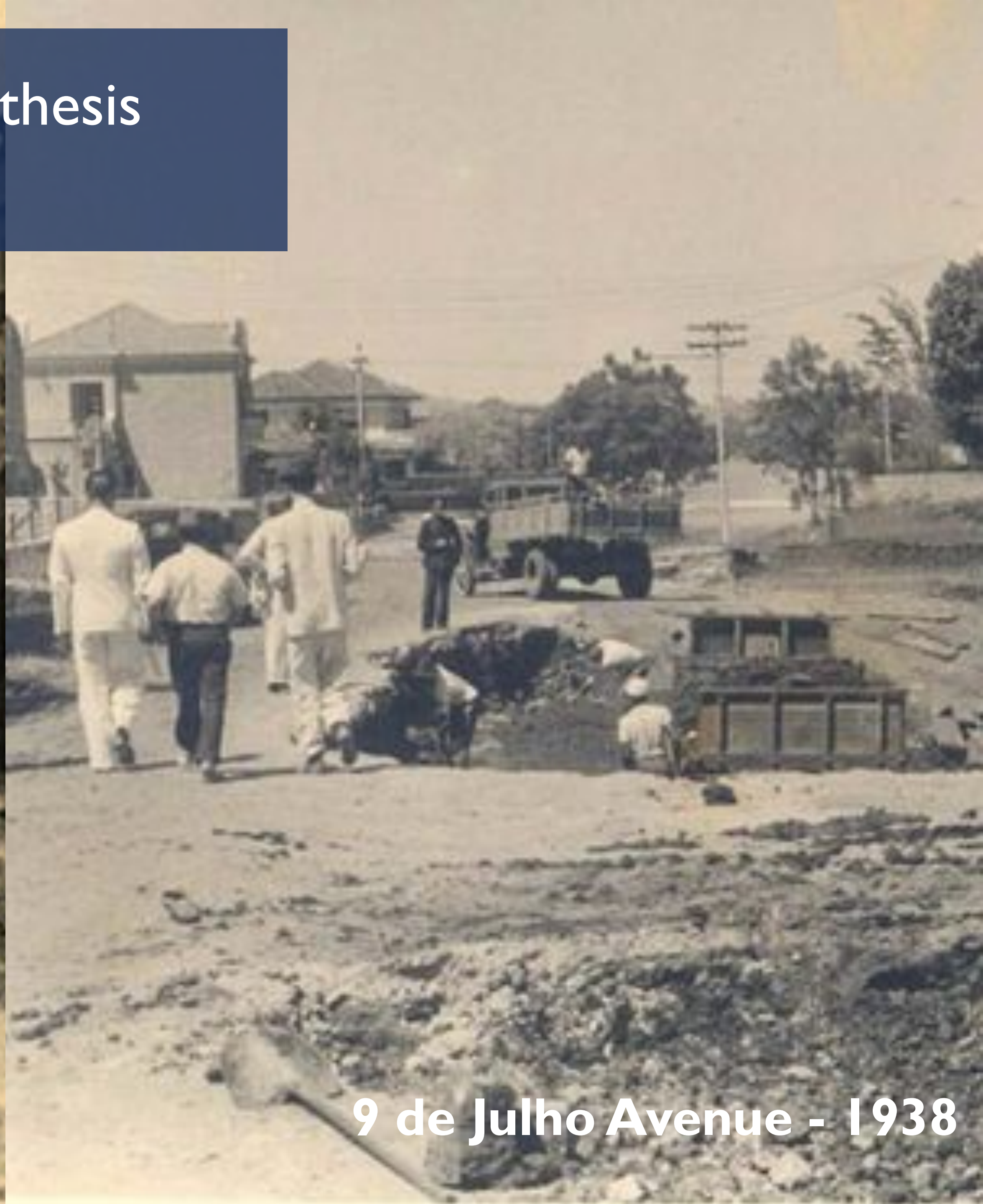

Teodoro Sampaio Street - 1904

“Orderliness” Hypothesis

(Levinson, 2008)



Rebouças Avenue - 1935



9 de Julho Avenue - 1938

Electric Trolley

Busses

Subway

BRT

Year	São Paulo City		Other cities of the Metropolitan Region of São Paulo	
	Total Population	10 years Increase	Total Population	10 years Increase
1872	31,385	-	-	-
1890	64,934	59.39%	-	-
1900	239,820	269.33%	-	-
1920	579,033	70.72%	-	-
1940	1,326,261	64.52%	241,784	-
1950	2,198,096	65.74%	424,690	75.65%
1960	3,781,446	72.03%	957,960	125.57%
1970	5,924,615	56.68%	2,215,115	131.23%
1980	8,493,217	43.35%	4,095,508	84.89%
1990	9,646,185	13.58%	5,798,756	41.59%
2000	10,434,252	8.17%	7,444,451	28.38%
2010	11,253,503	7.85%	8,430,472	13.25%


LOJAS
Firestone
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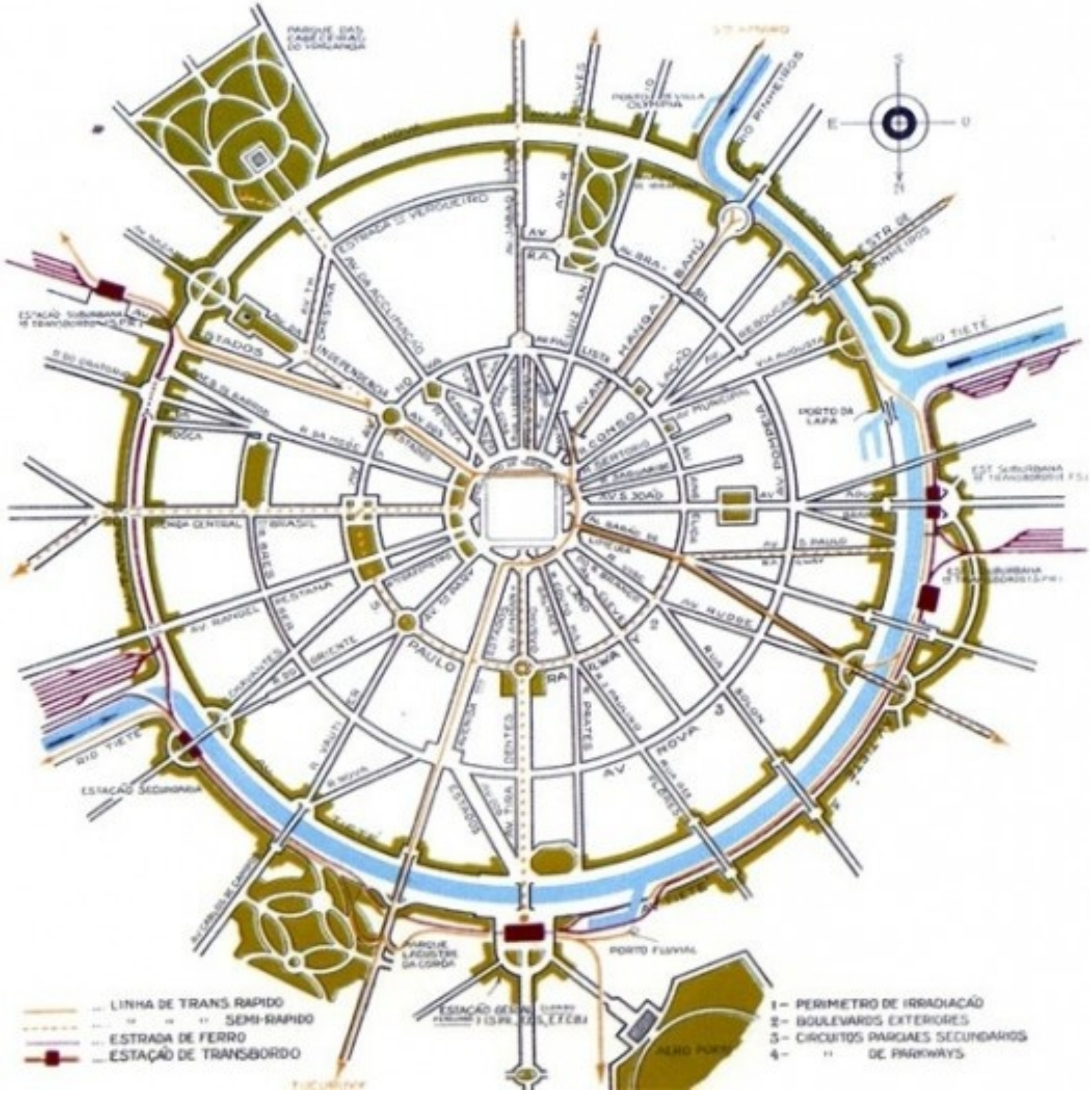
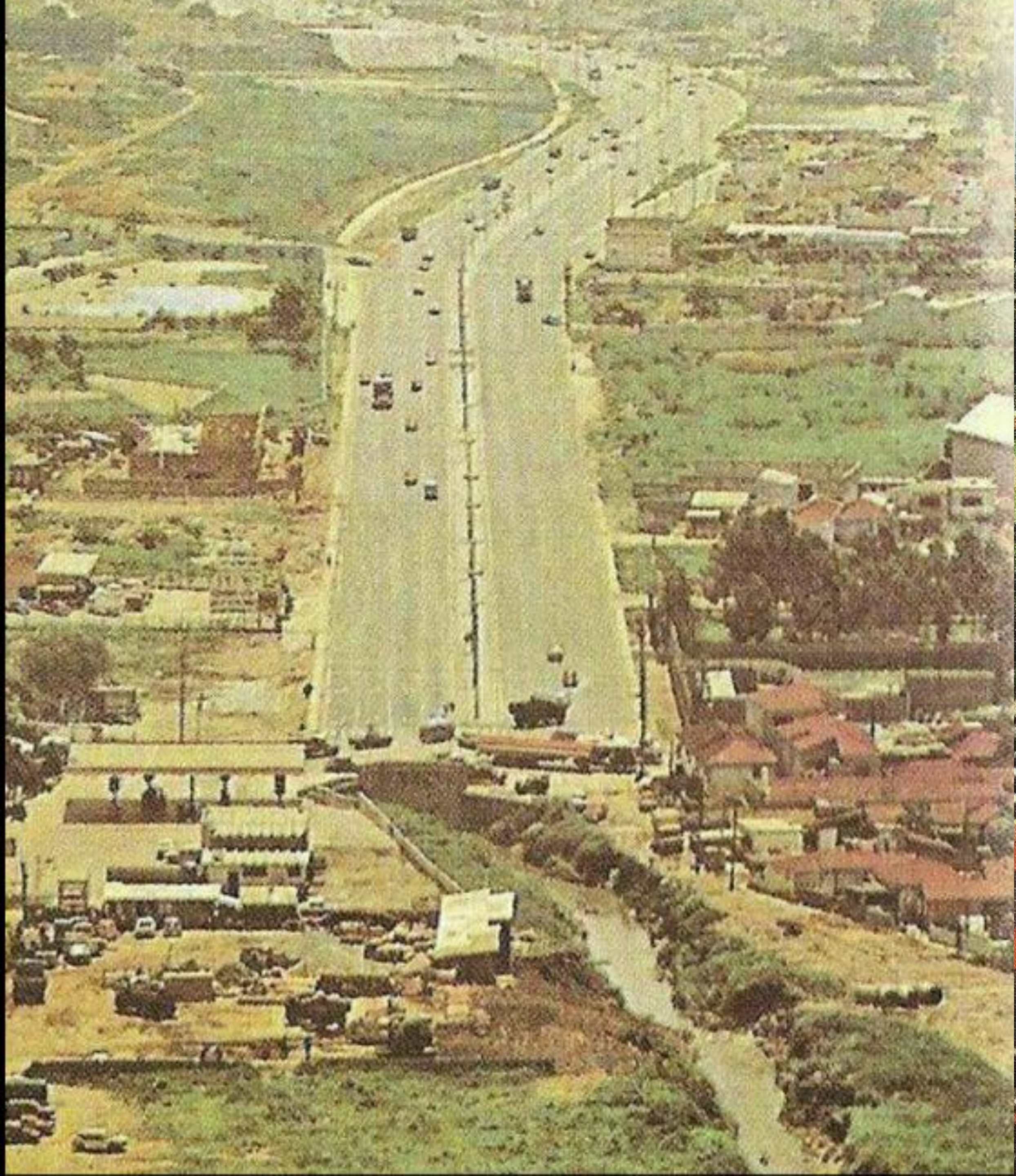
AVENUES AND ARTHERIAL ROADS DEVELOPMENT IN SÃO PAULO

AVENUES AND ARTHERIAL ROADS DEVELOPMENT IN SÃO PAULO



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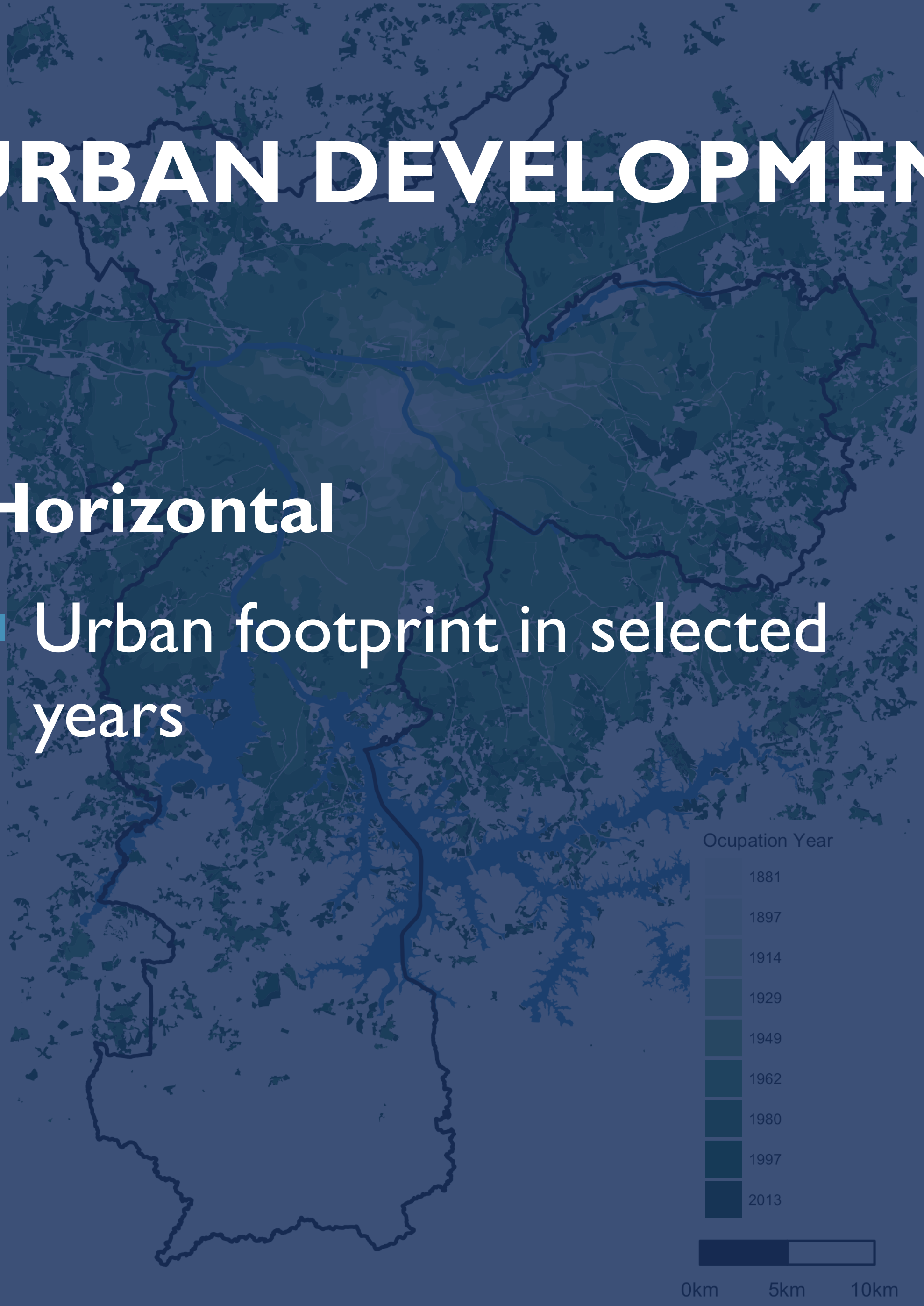
THE VALIDITY OF OUR IDENTIFICATION STRATEGY

Source of exogenous variation in the transportation variables of interest

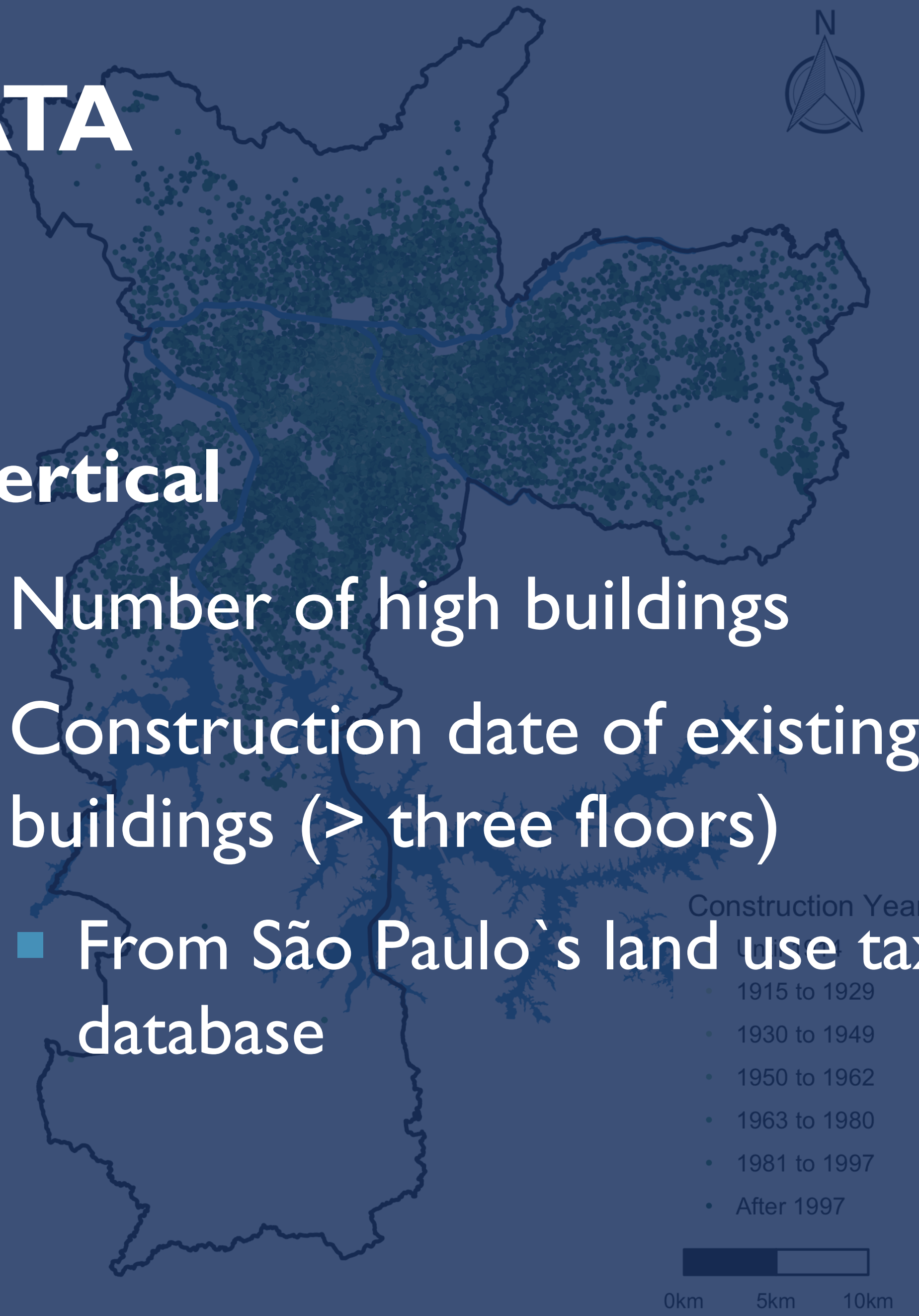
- several avenues in the city of São Paulo were built taking advantage of the free course left by rivers
- the subway lines built after the 1960s used the paths of old abandoned streetcar lines
- no clear reason to suppose that the presence of rivers or abandoned tramways in a region would directly influence its urban development

URBAN DEVELOPMENT DATA



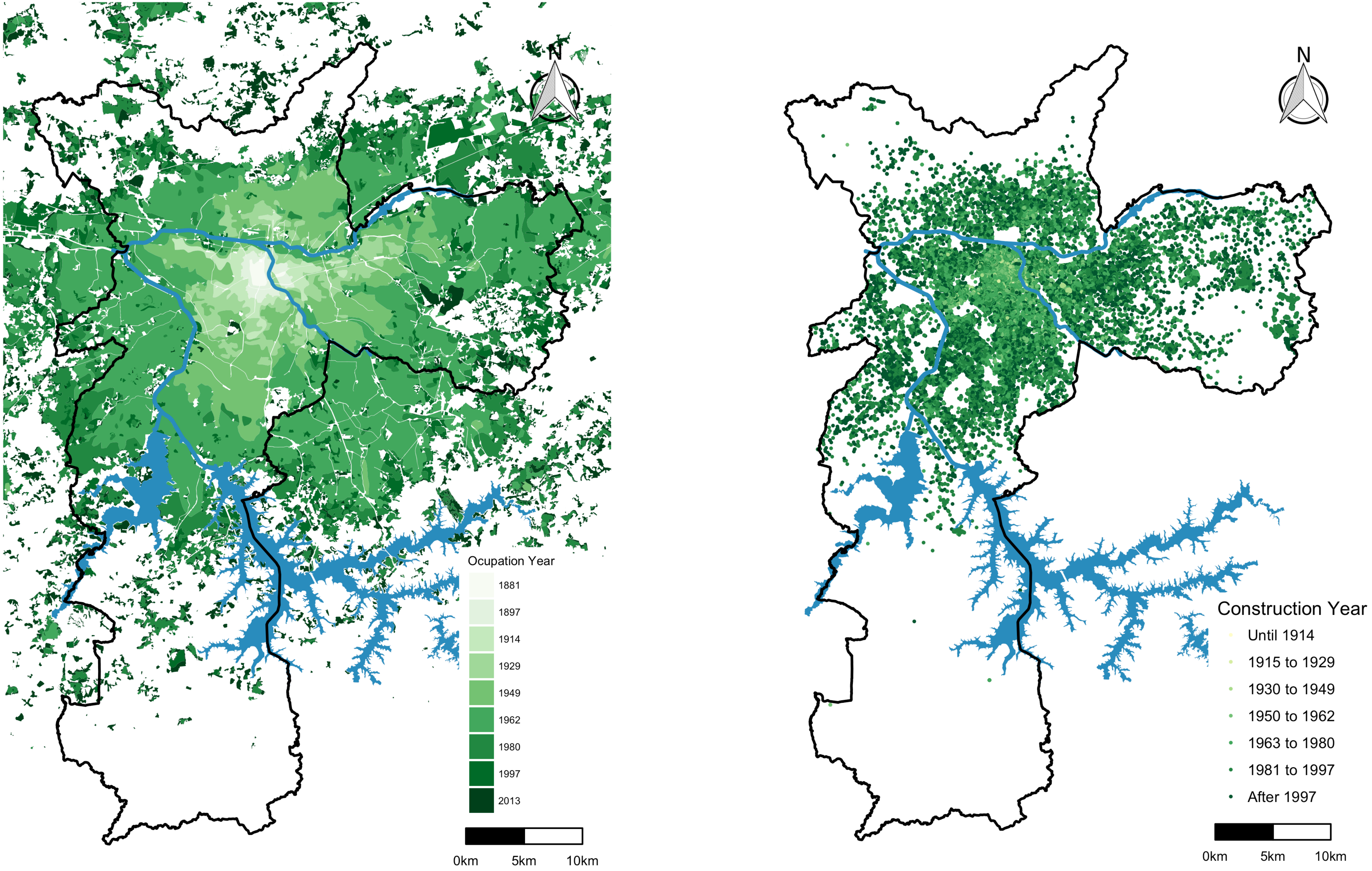
Horizontal

- Urban footprint in selected years



Vertical

- Number of high buildings
- Construction date of existing buildings (> three floors)
  - From São Paulo`s land use tax database


N
Ocupation Year
1881
1897
1914
1929
1949
1962
1980
1997
2013
0km
5km
10km
N
Construction Year
Until 1914
1915 to 1929
1930 to 1949
1950 to 1962
1963 to 1980
1981 to 1997
After 1997
0km
5km
10km

VARIABLES

Urban Development

- Urban area coverage in each period: $UA_{i,t} = U_{i,t}/A_i$
  - where $U_{i,t}$ is the urban area in the unit *i* at the time *t* and A_i is the area of the unit *i*
- Number of Buildings: $NB_{i,t}$
  - where $B_{i,t}$ is the number of buildings

Transportation Development

- Road (highways and avenues) network length in each period: $Rnt_{i,t}$
- Transit network length in each period: $Tnt_{i,t}$

First-stage Regression | Rivers on Avenues

	Dependent variable:		
		VarAvenues_t	
	(1)	(2)	(3)
Rivers_t	0.380***	0.378***	0.359***
	(0.126)	(0.127)	(0.120)
VarNBuildings_t		-0.00005	-0.001**
		(0.0003)	(0.001)
Dist CBD			-0.250***
			(0.062)
Zoning Limits			-0.738
			(1.059)
Natural Restrictions			0.109
			(9.350)
Constant	4.154***	4.172***	7.118***
	(0.257)	(0.282)	(0.773)
Observations	161	161	161
R^2	0.053	0.053	0.154
Adjusted R^2	0.047	0.041	0.127
Residual Std. Error	2.669 (df = 159)	2.677 (df = 158)	2.555 (df = 155)
F Statistic	8.939*** (df = 1; 159)	4.450** (df = 2; 158)	5.660*** (df = 5; 155)
Note:	*p<0.1; **p<0.05; ***p<0.01		

The same first stage regression using changes in the transit network instead of avenues reports not significant coefficients

A regression of the change in avenues network length in each cell between 1929 and 1997 on the change in the urbanized area yields a highly positive coefficient of 0.043 (se 0.008).

A regression of the length of river courses in a cell as the independent variable on the change in the urbanized area yields a coefficient that is not significantly different from 0 of -0.010 (se 0.014).

So, investment in urban roads is a good predictor of urban expansion in São Paulo, and rivers are unrelated to changes in the urbanized area.

First-stage Regression | Trolleys on Transit

	Dependent variable:		
	VarTransit_t		
	(1)	(2)	(3)
TrolleyLines_t	0.054^{***}	0.040^{**}	0.045^{***}
	(0.009)	(0.016)	(0.017)
VarNBuildings_t		0.0002	0.0001
		(0.0003)	(0.0003)
Dist CBD			-0.020
			(0.023)
Zoning Limits			-0.142
			(0.267)
Natural Restrictions			-1.534^{**}
			(0.701)
Constant	0.385^{***}	0.355^{***}	0.611^{**}
	(0.071)	(0.078)	(0.292)
Observations	161	161	161
R^2	0.207	0.209	0.217
Adjusted R^2	0.202	0.199	0.191
Residual Std. Error	0.907 (df = 159)	0.908 (df = 158)	0.912 (df = 155)
F Statistic	41.402^{***} (df = 1; 159)	20.921^{***} (df = 2; 158)	8.568^{***} (df = 5; 155)
Note:	*p<0.1; **p<0.05; ***p<0.01		

The same first stage regression using changes in avenues network instead of transit reports not significant coefficients.

2SLS regression of avenues on urban rate with river courses as instrumental variable

	Dependent variable:			
	VarTotalUrbanRate_t			
	(1A)	(2A)	(3A)	(4A)
VarAvenues_t	0.03	0.1	0.2***	0.1**
	(0.04)	(0.04)	(0.04)	(0.05)
VarNBuildings_t		-0.000***	-0.000***	-0.000
		(0.000)	(0.000)	(0.000)
DistCBD			-0.03*	-0.1***
			(0.02)	(0.02)
ZoningLimitsPercArea			-0.6***	
			(0.2)	
NaturalRestrPercArea			-0.1	
			(0.3)	
TotalUrbanRate_t0				-1.4***
				(0.2)
Constant	0.8***	1.0***	1.4***	2.0***
	(0.2)	(0.2)	(0.4)	(0.4)
Observations	161	161	161	161
R^2	-0.3	-0.5	-0.4	-0.3
Adjusted R^2	-0.3	-0.5	-0.4	-0.4
Residual Std. Error	0.3	0.4	0.4	0.4
Note:	*p<0.1; **p<0.05; ***p<0.01			

Weak instruments	0.002736 ***	Pass
Wu-Hausman	0.000558 ***	Pass

2SLS regression of transit on number of buildings with streetcar routes as instrumental variable

	Dependent variable:			
	VarNBuildings_t			
	(1B)	(2B)	(3B)	(4B)
VarTransit_t	1,075.5***	1,236.3***	1,359.5***	719.0**
	(148.9)	(182.3)	(293.5)	(347.1)
VarTotalUrbanRate_t		667.3*	947.4	308.3
		(367.6)	(607.1)	(343.6)
DistCBD			4.1	-14.0
			(30.3)	(21.0)
ZoningLimitsPercArea			720.8	
			(602.8)	
NaturalRestrPercArea			2,418.1**	
			(961.9)	
NBuildings_t0				44.4*
				(26.4)
Constant	-288.2***	-786.4**	-1,169.3	-188.9
	(98.3)	(336.1)	(840.1)	(565.9)
Observations	161	161	161	161
R^2	-2.3	-3.2	-3.9	-0.5
Adjusted R^2	-2.3	-3.2	-4.1	-0.5
Residual Std. Error	987.4	1,117.2	1,227.8	670.1
Note:	*p<0.1; **p<0.05; ***p<0.01			

Weak instruments	0.00000139 ***	Pass
Wu-Hausman	<2e-16 ***	Pass

2SLS regression of avenues and transit on urban rate and number of buildings with river courses and streetcar routes as instrumental variable

	Dependent variable:				*Dependent variable:*			
	VarTotalUrbanRate_t				VarNBuildings_t			
	(1A)	(2A)	(3A)	(4B)	(1B)	(2B)	(3B)	(4B)
VarAvenues_t	0.039***	0.041***	0.057***	0.0491**	-74.1	-39.9	-27.2	-41.6
	(0.0118)	(0.0117)	(0.0110)	(0.0176)	(106.4)	(110.1)	(120.1)	(58.8)
VarTransit_t	-0.2564***	-0.2427	-0.1035	-0.3267	1,047.7***	1,261.1***	1,351.2***	665.7**
	(0.0618)	(0.1957)	(0.2369)	(0.2055)	(156.3)	(204.9)	(291.2)	(323.9)
VarNBuildings_t		-0.00001	-0.0003	-0.0003		832.4	1,044.1	417.1
		(0.0002)	(0.0002)	(0.0002)		(582.4)	(696.0)	(337.5)
DistCBD			-0.0268*	-0.0401**			-1.5	-23.9
			(0.0153)	(0.0202)			(37.6)	(23.8)
ZoningLimitsPercArea			-0.5803***				747.0	
			(0.1797)				(572.1)	
NaturalRestrPercArea			-0.2473				2,421.5***	
			(0.4949)				(938.3)	
NBuildings_t0				0.0265				47.2**
				(0.0177)				(24.0)
Constant	0.9556***	0.9568***	1.3898***	1.4925***	89.1	-706.3*	-1,039.4	71.7
	(0.2461)	(0.2405)	(0.3827)	(0.4953)	(537.8)	(400.2)	(1,028.4)	(642.7)
Observations	161	161	161	161	161	161	161	161
R^2	-0.6882	-0.6519	-0.3230	-0.9772	-2.0	-3.2	-3.7	-0.2
Adjusted R^2	-0.7096	-0.6834	-0.3745	-1.0409	-2.1	-3.2	-3.9	-0.2
Residual Std. Error	0.3994	0.3963	0.3581	0.4364	952.0	1,119.8	1,207.4	606.1
Note:	*p<0.1; **p<0.05; ***p<0.01							

2SLS regression of avenues and transit on residential and commercial built up area with river courses and streetcar routes as instrumental variables

	Dependent variable:				*Dependent variable:*			
	VarResBuiltAreaRate_t				VarComBuiltAreaRate_t			
	(1A)	(2A)	(3A)	(4A)	(1B)	(2B)	(3B)	(4B)
VarAvenues_t	-34,471.1	-26,050.7	-22,733.1	-25,938.1	-1,682.8	6,196.1	10,738.1	7,937.7
	(29,001.1)	(26,725.7)	(19,621.3)	(19,783.6)	(30,142.3)	(30,889.3)	(40,224.1)	(57,496.3)
VarTransit_t	211,670.9***	264,283.8***	161,500.4***	160,023.6**	308,702.7***	357,931.8***	456,856.4***	665,262.4
	(40,372.8)	(60,193.0)	(61,958.5)	(79,938.8)	(71,066.3)	(78,720.0)	(105,645.8)	(554,164.1)
VarTotalUrban Rate_t		205,224.9	145,884.8	110,387.1		192,025.9	327,269.0	425,919.7
		(153,853.2)	(139,276.6)	(118,143.0)		(168,407.8)	(236,628.8)	(539,077.6)
DistCBD			-24,443.4***	-23,097.3***			12,368.9	24,694.6
			(7,847.7)	(7,370.8)			(13,112.7)	(30,702.3)
Zoning Limits			179,507.7*				271,922.8	
			(99,799.1)				(198,122.2)	
Natural Restrictions			451,445.0**				709,094.0**	
			(183,330.7)				(342,441.1)	
Res/Com Built Area Base Line				-47.7				-50.4
				(171.2)				(123.2)
Constant	188,317.8	-7,794.9	285,260.6	336,985.7*	-96,479.4	-279,979.1**	-600,002.7*	-828,592.3
	(146,180.2)	(108,119.4)	(209,585.3)	(175,701.2)	(158,049.3)	(135,363.4)	(362,245.1)	(860,673.9)
Observations	161	161	161	161	161	161	161	161
R^2	-0.5	-0.7	0.1	0.04	-2.2	-3.2	-5.7	-13.4
Adjusted R^2	-0.5	-0.7	0.02	0.01	-2.2	-3.3	-6.0	-13.9
Residual Std. Error	267,742.2	290,218.2	218,061.4	219,631.2	280,582.1	324,449.2	412,166.3	602,829.9
Note:	*p<0.1; **p<0.05; ***p<0.01							

- Each kilometer of new avenues and arterial roads generated a 5% increase in the local urbanization rate between 1929 and 1997.
- Each additional kilometer of rail transit lines was responsible for an increase of 130% in the number of tall buildings in the region.
  - Commercial real estate react more intensely to investments in transit than the residential real estate market
- First joint causal inference of urban roads and transit different impacts on horizontal and vertical urban development.
- Strengthen pro-transit arguments: promote not only sustainable mobility, but also sustainable urbanization.
  - argument based on anecdotal evidence and historical observation, but with little empirical supporting evidence