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Transportation Safety Performance of US Bus Transit Agencies and Population Density: A Cross-Sectional Analysis (2008-2014)

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Outline

1. Background
2. Methodology
3. Data and descriptive statistics
4. Regression results for fatalities
5. Regression results for injuries
6. Discussion of results
7. Summary and potential for future research

Background

- The paper examines the transportation safety performance of transit agencies providing public bus service in the US by using data from the National Transit Database (NTD)
- Uses NTD data for a seven-year period from 2008 to 2014
  - 3,853 observations for 651 public transportation agencies in 50 states
- Seven types of bus transit fatalities and injuries (including passengers, operators, pedestrians, bicyclists)
- Main explanatory variable: urban density obtained from the US Census figures
- Other explanatory variables: total agency revenue miles, unlinked passenger trips, agency fleet size, and urban population

Urban density and transit safety

- Increasing population levels are expected to influence crash dynamics in potentially countervailing directions.

1. Along with a general increase in traffic volumes, the traffic composition and the types of roadway users, such as the share of pedestrians and bicyclists, are also expected to increase.
2. Due to the increasingly urban nature of the roadway environment, as the population density increases, factors such as higher traffic levels, reduced speed limits, and modified driver and road user behavior are expected to lead to safety improvements.

Model specification

- A negative binomial model specification estimates the probability $P\ (n_i)$ of *n* incidents occurring in transit agency *i* as:

$$P\ (n_i) = \left(\frac{1/\alpha}{(1/\alpha)+\lambda_i}\right)^{1/\alpha} \frac{\Gamma[(1/\alpha)+n_i]}{\Gamma(1/\alpha)n_i!} \left(\frac{\lambda_i}{(1/\alpha)+\lambda_i}\right)^{ni}$$

- The mean number of safety incidents occurring in agency i during the analysis period, λ_i , is a linear function of the covariates:

$$\lambda_i = EXP\ (\beta X_i + \varepsilon_i)$$

where

- β is a vector of estimated coefficients; X_i is a vector of variables associated with agency *i* (e.g., revenue miles driven, agency size, unlinked passenger trips, etc.); ε_i is a gamma-distributed error term with mean of one and variance of α.

Descriptive statistics: Agency Variables

Agency variables	Mean	Median	Maximum	Minimum	Std. Dev.
Urban area pop. density	2,618	2,127	9,857	759	1,536
Urban area population	1,584,524	296,668	12,191,715	7,586	3,008,003
Unlinked pass. trips (UPT)	9,411,046	1,157,470	902,640,956	90	43,864,942
Agency fleet size (VOMS)	90	23	3,933	1	256
Vehicle rev. miles (VRM)	3,380,372	930,077	102,920,091	4,947	8,573,293

Descriptive statistics: Fatalities

Fatalities	Mean	Median	Max	Min	SD
Passenger	0.01	0	3	0	0.11
Operator	0	0	1	0	0.06
Other vehicle occupants	0.05	0	5	0	0.28
People waiting or leaving	0.02	0	4	0	0.17
Bicyclists	0.01	0	3	0	0.11
Pedestrians in crossing	0.02	0	4	0	0.17
Pedestrians not in crossing	0.02	0	3	0	0.17

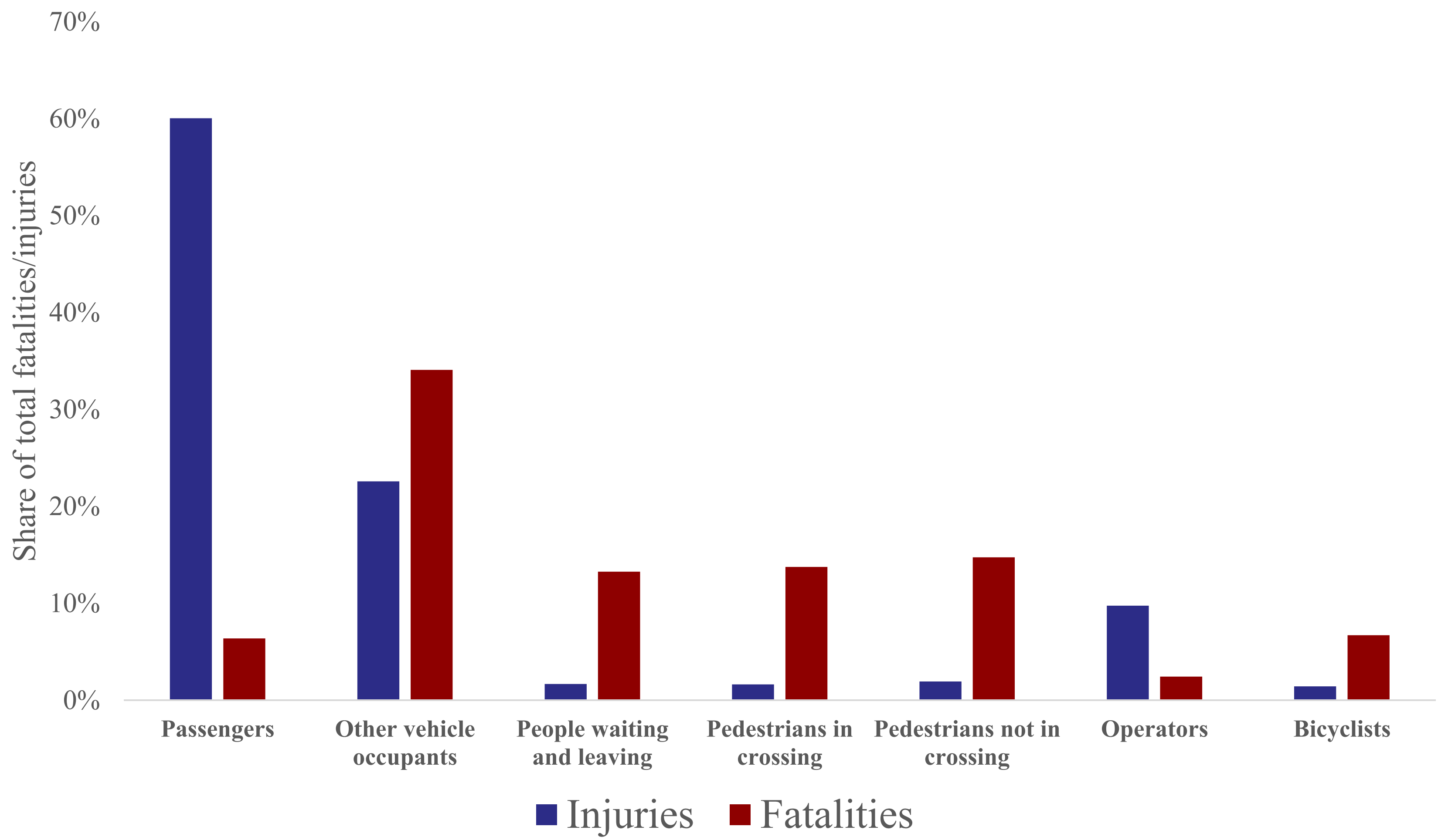
Descriptive statistics: Injuries

Injuries	Mean	Median	Max	Min	SD
Operator	1.27	0	160	0	7.71
Passenger	7.81	0	388	0	29.42
Other vehicle occupants	2.94	0	185	0	10.87
People waiting or leaving	0.22	0	30	0	1.25
Bicyclists	0.19	0	19	0	0.87
Pedestrians in crossing	0.21	0	17	0	1.08
Pedestrians not in crossing	0.25	0	27	0	1.27

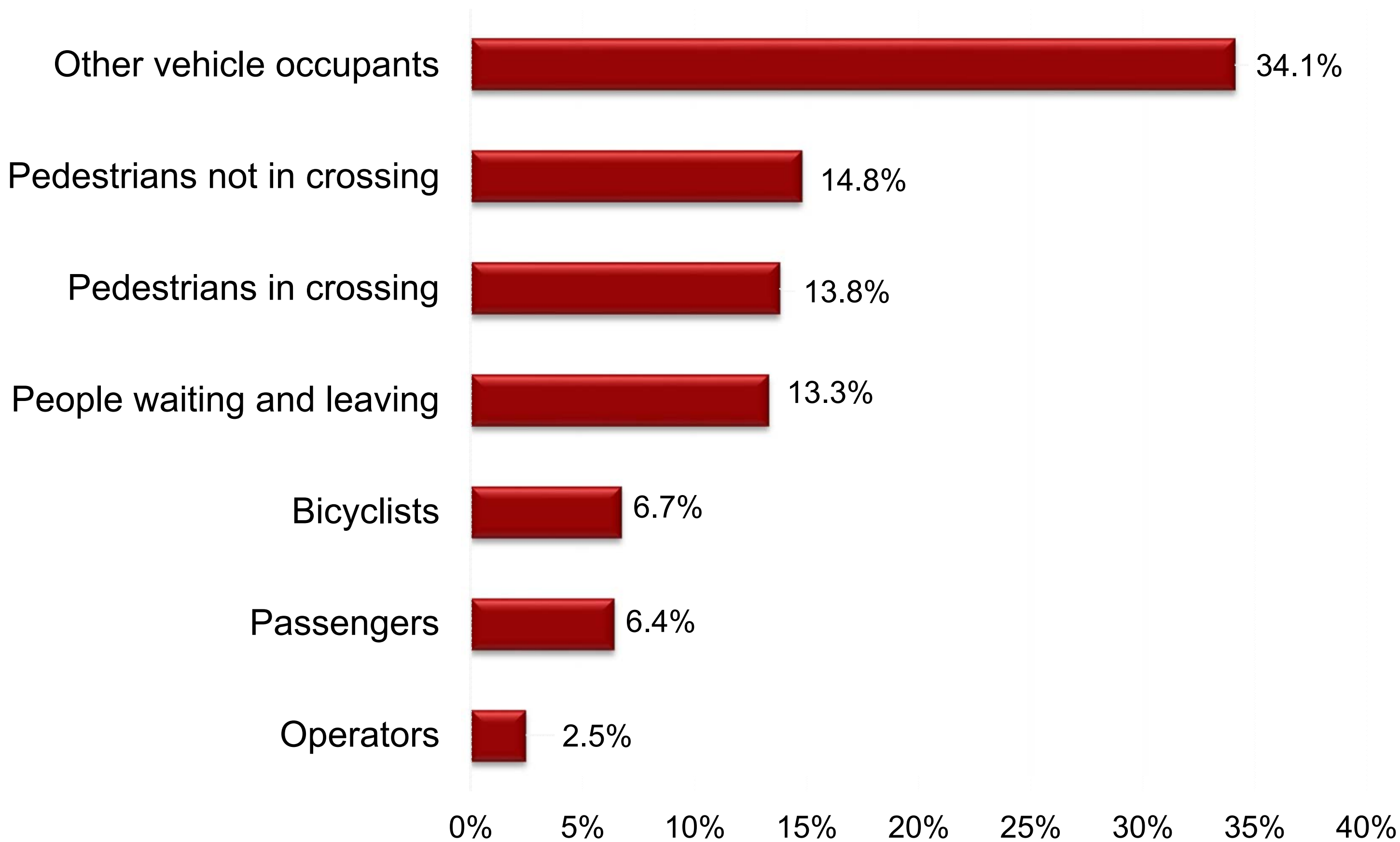
Passenger injuries dominate injury types

- While injuries sustained by passengers dominate the bus transit injuries, the leading incident types for fatalities are other vehicle occupants and pedestrians.

Share of total fatalities/injuries reported



Leading fatality types reported



Summary of regression results by fatality type

	Pass.	Oper.	Occup. of other veh.	People wait./leav.	Bicyclists	Peds in cross.	Peds not in cross.
Constant	**-21.758*** **	**-30.123* **	**-21.30*** **	**-26.37*** **	**-23.33*** **	**-16.945*** **	**-17.410*** **
	(4.488)	(18.019)	(2.134)	(3.987)	(3.987)	(3.086)	(2.635)
No. of total	0.001	0.000	0.002	-0.001	**-.00958* **	-0.003	-0.003
collisions	(0.005)	(0.016)	(0.003)	(0.005)	(0.005)	(0.003)	(0.003)
Veh. rev.	2.052	2.827	**2.965*** **	**4.065*** **	0.806	-0.248	**1.581** **
miles (log)	(1.485)	(2.907)	(0.587)	(1.087)	(1.173)	(0.717)	(0.716)
UPT (log)	0.611	-0.354	-0.018	0.471	**1.773** **	**2.398*** **	0.806
	(1.153)	(1.833)	(0.467)	(0.823)	(0.873)	(0.611)	(0.564)
Fleet size	0.000	0.000	**-.0005*** **	**-.0013*** **	0.000	0.000	0.000
	(0.000)	(0.001)	(0.000)	(0.000)	(0.000)	(0.000)	(0.000)
Pop. density	1.184	0.277	-0.152	-0.716	-0.234	-0.649	**-1.690** **
(log)	(1.100)	(2.799)	(0.563)	(1.107)	(1.352)	(0.864)	(0.679)
Population	-0.766	1.181	-0.061	**-.823* **	0.416	0.089	**.609* **
(log)	(0.550)	(1.450)	(0.254)	(0.460)	(0.642)	(0.363)	(0.317)

Note: *, **, * indicate significance at the 1%, 5%, and 10% level, respectively; standard errors shown in parentheses.**

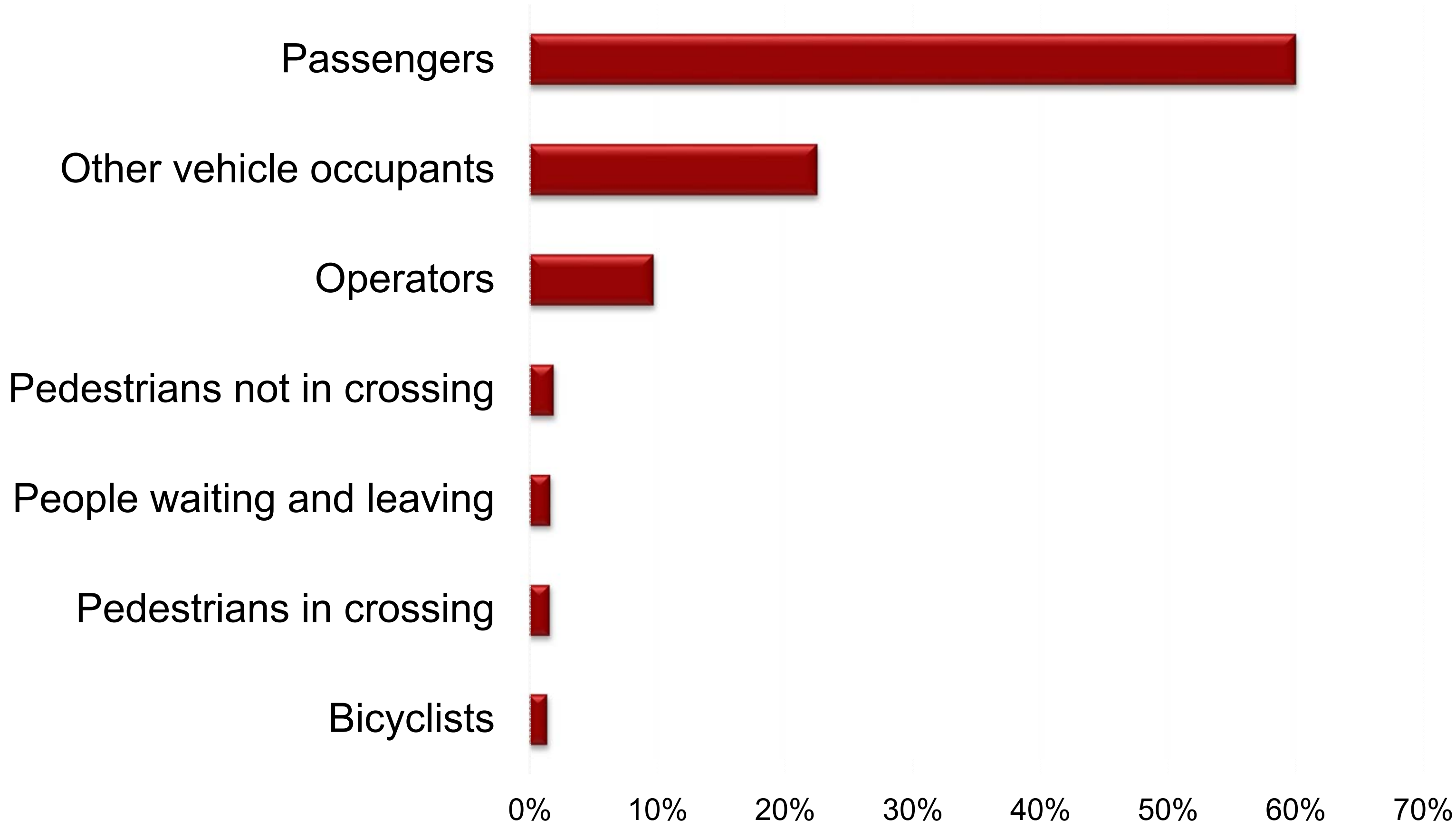
Regression results for fatality incidents

- Even though there is a lack of statistically significant relationship for the number of trips taken and revenue miles for some fatality types, these regressions tend to be for those fatality types that are extremely infrequent in the sample
- For the fatality types with higher frequencies, the number of trips taken and revenue miles *are* found to be statistically significant
- Agency fleet size found provide improvements in bus transit safety overall

Regression results for fatality incidents

- Unlinked passenger trips could be indirectly capturing the pedestrian volumes exposed to crash risks
  - Fatalities involving pedestrians in crossings and bicyclists have statistically significant positive relationships with unlinked passenger trips
- On the other hand, increasing urban density levels have a reducing effect on fatalities that do *not* take place on pedestrian crossings, arguably due to changed driver and pedestrian behavior patterns in more urban environments
- The negative but small effect of agency size on number of fatalities is consistent with same effect observed between the agency size and injuries

Leading injury types reported



Summary of regression results by injury type

	Pass.	Oper.	Occup. of other veh.	People wait./leav.	Bicyclists	Peds in cross.	Peds not in cross.
Constant	**-9.319*** **	**-12.26*** **	**-13.43*** **	**-24.45*** **	**-22.62*** **	**-21.513*** **	**-21.731*** **
	(0.711)	(0.779)	(0.573)	(1.678)	(1.239)	(1.548)	(1.317)
No. of total collisions	**.0364*** **	**.0171*** **	**.0196*** **	**.0053** **	**.008*** **	**.005*** **	**.0102*** **
	(0.003)	(0.001)	(0.001)	(0.002)	(0.001)	(0.002)	(0.001)
Veh. rev. miles (log)	**1.89*** **	**1.528*** **	**1.821*** **	**2.233*** **	**.7531** **	**.570* **	**1.301*** **
	(0.170)	(0.223)	(0.153)	(0.471)	(0.315)	(0.336)	(0.368)
UPT (log)	**.799*** **	**.799*** **	**.609*** **	**1.683*** **	**1.862*** **	**2.298*** **	**1.747*** **
	(0.110)	(0.165)	(0.105)	(0.376)	(0.256)	(0.286)	(0.305)
Fleet size	**-.001*** **	**-.0003*** **	**-.0007*** **	**-.001*** **	**-.001*** **	**-.0005*** **	**-.0009*** **
	(0.000)	(0.000)	(0.000)	(0.000)	(0.000)	(0.000)	(0.000)
Pop. density (log)	**-3.038*** **	**-1.774*** **	**-1.076*** **	**-1.223*** **	**.941*** **	-0.032	-0.236
	(0.197)	(0.230)	(0.149)	(0.431)	(0.269)	(0.355)	(0.354)
Pop. (log)	**.545*** **	**.400*** **	**.281*** **	0.072	-0.024	0.021	0.029
	(0.060)	(0.087)	(0.054)	(0.219)	(0.120)	(0.158)	(0.167)

Note: *, **, * indicate significance at the 1%, 5%, and 10% level, respectively; standard errors shown in parentheses.**

Regression results for injury incidents

- The regression models perform substantially better in explaining total injuries reported by the transit agencies
- Three injury types account for more than 90 percent of all reported injuries.
  - Passengers
  - Occupants of other vehicles
  - Operators
- For these three groups, all independent variables included in the model specification are statistically significant at practically any level.

Clear and negative relationship between all injury types and population density

- Highest coefficient size among all variables; potentially surpassing the effects of agency revenue miles, unlinked passenger trips, and area population
- Increased population density levels also provide improvements for injuries sustained by people waiting for and leaving public motorbuses
- As expected, UPT and revenue miles have positive and significant relationships with transit injuries
- Larger agency size tends to reduce risk of injuries all injury types

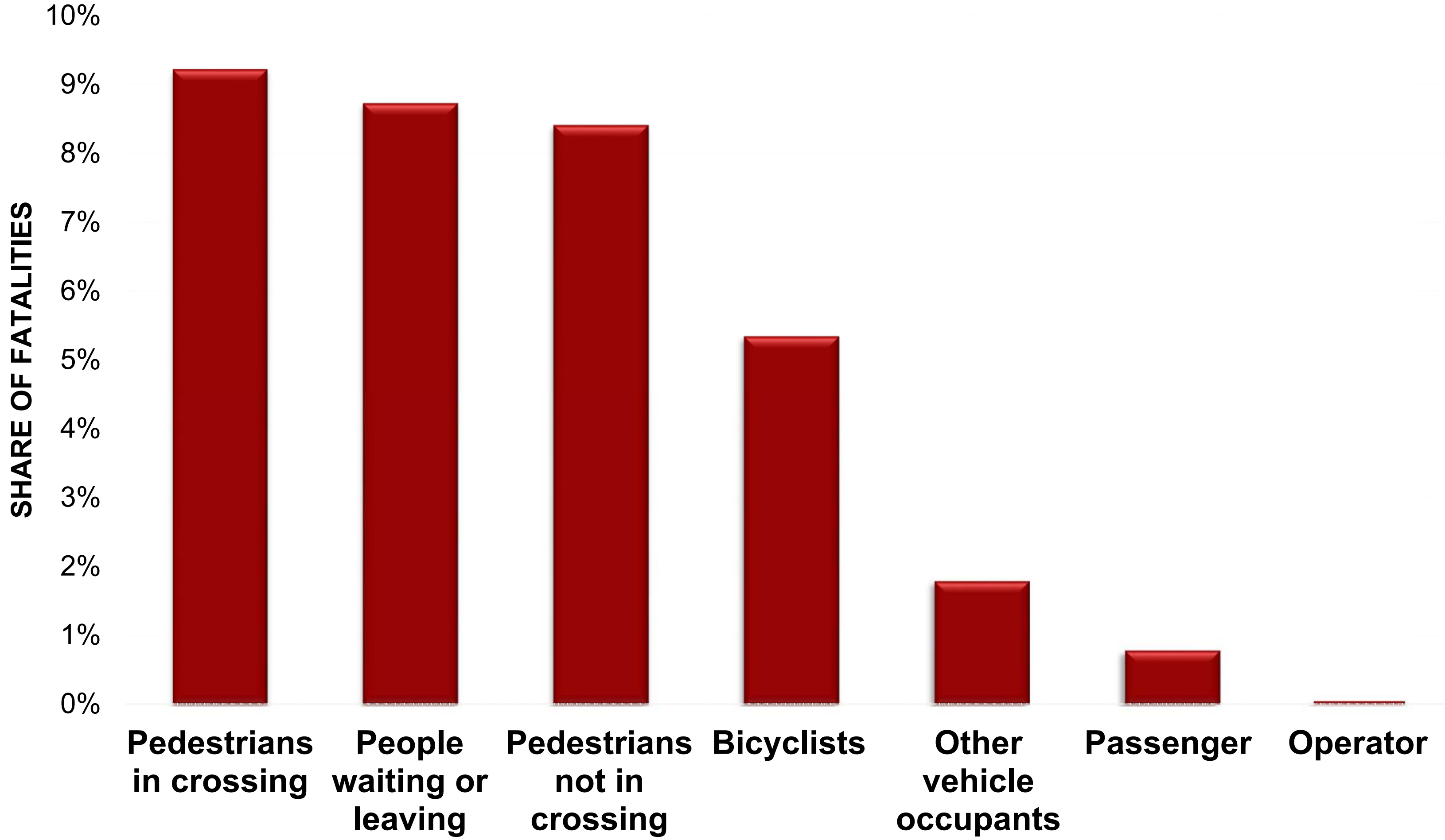
Bicyclist injuries and urban density

- The injuries sustained by bicyclists suggests the sole exception to the desirable effects of urban density
  - Arguably, the same safety benefits introduced by urban environments fall short of the marked increases in safety risks induced by higher bicyclist volumes

Pedestrians far more vulnerable to fatalities than passengers

- As expected, substantial differences in incident types, especially among passengers and pedestrians
- For incidents involving pedestrians, the fatality risks for pedestrians are considerably higher than transit passengers.
- For example, approximately nine percent of total incidents for pedestrians result in fatal outcomes, whereas the same ratio is considerably smaller for other vehicle occupants and bus passengers

Conditional share of fatalities given an incident type



Limitations

- The number of fatalities seems to be hardest to model, in part due to their low occurrence in the dataset
- Assigning a single urban density level to transit agencies may oversimplify the agencies' complex operating environments
- Potential multicollinearity remains a problem
- The availability of alternative transit systems such as light-rail or heavy-rail systems could be captured to examine potential interaction effects

Summary

- Clear majority of bus transit injuries were sustained by passengers while pedestrians are far more vulnerable to fatalities than passengers (255 vs. 39 fatalities)
- Urban density levels are associated with improvements in the safety performance of the public transit agencies
  - Cities with higher population densities also seem to be safer for pedestrians: interesting because denser areas would also be expected to result in higher transit ridership
- Yet higher levels of unlinked passenger trips are linked to increases in fatalities for bicyclists and pedestrians in crossings as the pedestrian and bicyclist volumes rise in more urban environments
  - Similarly, bicyclist injuries tend to rise in more urban areas

Areas for further research

- Results suggest distinct safety mechanisms may be at play in explaining the variance observed among transit agencies
- Potential explanations for these observations could include
  - lower speed levels due to congestion and speed limits,
  - pedestrian-friendly urban environments
  - enhanced integration of public transportation vehicles to the road network
  - adaptive driving behavior of the public toward transit vehicles in more urban settings.

- Further research in this area can identify which of these dynamics play more prominent roles in explaining the reduced levels of crashes in urban environments.

Q&A and discussion