Share of Mass Transit Miles Traveled and Reduced Motor Vehicle Fatalities in Major Cities of the United States

Jim P. Stimpson, Fernando A. Wilson, Ozgur M. Araz, and
Jose A. Pagan

ABSTRACT *The USA leads the developed world in motor vehicle fatalities, presenting a critical public health threat. We examined whether an increasing share of mass transit use, relative to vehicle miles traveled on public roads, was associated with reduced motor vehicle fatalities. We used annual city-level data for the USA from 1982–2010 provided by the Fatality Accident Reporting System, the Texas A&M Transportation Institute, the Census Bureau, and the National Oceanic and Atmospheric Administration to estimate a structural equation model of the factors associated with mass transit miles and motor vehicle fatalities. The final analytic data included 2,900 observations from 100 cities over 29 years. After accounting for climate, year, and the economic costs of driving, an increasing share of mass transit miles traveled per capita was associated with reduced motor vehicle fatalities. The costs of congestion to the average commuter and gas prices were positively associated with increasing the share of mass transit miles traveled. The economic costs of driving increased over time, while both the fatality rate and the share of mass transit miles traveled decreased over time. Increasing the share of mass transit miles traveled may be associated with fewer motor vehicle miles traveled. Increasing mass transit uptake may be an effective public health intervention to reduce motor vehicle fatalities in cities.*

KEYWORDS *Motor vehicle, Transportation, Mortality, Automobile driving*

INTRODUCTION

Mass transit has been linked to economic development, reduced traffic congestion and emissions, and better access to affordable transportation options.¹ In a poll of the American public's spending priorities, mass transit ranked 10th, higher than support for funding highways and bridges.² Aside from the purported benefits of mass transportation, such as job growth and lower emissions, driving is substantially more dangerous than riding mass transit. The World Health Organization predicts that road fatalities will be the fifth leading cause of death worldwide by 2030, and the USA leads most industrialized nations in numbers of fatalities per capita.³ Compared to more than 30,000 deaths from fatal crashes on public roads each year, there are fewer than 150 fatalities on all mass transit combined (a 200-fold difference), and most of those fatalities

Stimpson and Wilson are with the Department of Health Services Research and Administration, College of Public Health, University of Nebraska Medical Center, NE, USA; Araz is with the Department of Health Promotion, Social & Behavioral Health, College of Public Health, University of Nebraska Medical Center, NE, USA; Pagan is with the New York Academy of Medicine, New York, USA.

Correspondence: Jim P. Stimpson, Department of Health Services Research and Administration, College of Public Health, University of Nebraska Medical Center, NE, USA. (E-mail: james.stimpson@unmc.edu)

are due to collisions of nonpassenger trains with cars or persons that were unauthorized to be on the tracks.⁴

Most research on motor vehicle fatalities has focused on measuring the benefits of vehicle safety, driver behavior, and law enforcement in reducing traffic fatalities.^{5–14} For example, there have been numerous studies evaluating the benefits of seat belts, motorcycle helmets, and other safety devices and evaluating the effectiveness of improving licensing requirements, traffic enforcement, and laws against drunk driving, cell phone use, and texting.^{5–19} However, some people may drive more recklessly with increased vehicle safety.²⁰ Distracted driving is a major road hazard, but the effectiveness of laws prohibiting cell phone use and other forms of distraction are mixed.^{17,18,21–28} By offering a much safer alternative to driving, and thus reducing the exposure to the risk of the roadways, mass transit circumvents the challenges of trying to transform people into safer drivers.

The relationship between mass transit use and road fatalities is complex.²⁹ Calculating an estimate of the potential benefits of mass transit in reducing motor vehicle fatalities is important, despite these challenges, because mass transit systems are usually taxpayer funded and have high capital and operating costs. Thus, their creation or expansion may be controversial, especially in times of economic distress. Establishing a relationship between increased utilization of mass transit and road fatalities may generate greater political urgency to act in support of mass transit. Therefore, this study examined whether an increasing share of mass transit use, relative to vehicle miles traveled on public roads, was associated with reduced motor vehicle fatalities.

METHODS

Data Sources

Our study merges various sources of city-level data for the period 1982–2010. Comprehensive data on road fatalities is provided by the Fatality Accident Reporting System (FARS). This database records every vehicular/pedestrian accident occurring on public roadways in the USA where there is at least one fatality resulting from the accident within 30 days. Information is compiled from various records, including police accident reports, vehicle registration and driver licensing files, vital/death certificates, and coroner, hospital, and emergency medical reports.³⁰

We merged annual, city-level data from the Texas Transportation Institute (TTI) urban mobility report with the FARS using year and city identifiers. The TTI collects mass transit utilization and commuting data for 100 urban areas in the USA.³¹ The cities include the most populous urban areas in the USA, ranging from Eugene, OR, to New York City. Ridership data includes number of annual passenger miles traveled and annual unlinked passenger trips for each city and incorporates data on all forms of mass transit available for city residents. Details about the methodology for the TTI data including details on data sources and calculation of measures can be found in the appendix of the urban mobility report.³¹ We also merged data on city population estimates from the US Census Bureau and climate data at the city level from the National Oceanic and Atmospheric Administration.^{32,33} The final analytic data included 2,900 observations from 100 cities over 29 years.

Measures

The primary outcome variable was motor vehicle deaths per 100,000 population using both the FARS and Census data. The outcome was not normally distributed;

therefore, we performed a zero-skewness log transformation. The main predictor variable was the share of mass transit utilization at the city level. We calculated the share of mass transit miles traveled per capita by first dividing the annual mass transit miles traveled per capita into the combined annual miles traveled per capita for both mass transit and motor vehicles and then multiplying by 100. Fuel cost was measured in inflation-adjusted dollars per gallon measured daily and then the average value of daily gas values over a given year was used to create an average annual cost. The inflation-adjusted cost of roadway congestion was measured as an index, which was calculated by TTI based on the cost of daily vehicle hours of delay (which uses data on daily vehicle miles of travel and traffic speed) and cost of wasted fuel (which uses data on fuel consumption). Therefore, this index measure parsimoniously accounts for overcapacity of the road system by measuring a number of interrelated factors such as number of commuters, commercial traffic, lane capacity, fuel usage, and travel time.³¹ Climate was measured by annual precipitation and temperature at the city level. The climate data have been annualized and adjusted by NOAA for systematic, nonclimatic changes that bias temperature and precipitation trends.³³ Year was included to account for annual changes in traffic fatalities, annual changes in economic conditions, and annual changes in travel behavior. We squared year to account for nonlinear, annual variations.

Analytic Strategy

Stata 13 was used to perform all analyses (StataCorp, College Station, TX). We employed a structural equation model (SEM) using maximum likelihood estimation and observed information matrix standard errors. We reported standardized coefficients for the parameter estimates and the entire model fit indices available in Stata. We did not have any missing data in our analytic sample. We chose SEM because the relationships between the variables required a path analysis to adequately model the endogenous relationship between the outcome (motor vehicle fatality rate), the exogenous factors (year, climate), the economic costs of driving (congestion, gas), and the share of mass transit miles traveled. This analytic approach also accounts for correlated error between variables (e.g., our model correlates the shared error variance between congestion cost and gas prices).

We conducted a sensitivity analysis given that more than one out of four mass transit commuters in the USA are located in New York City, and 56 % of NYC households do not own a car.³⁴ We ran the structural equation model with New York/Newark excluded from the analysis. The results were substantively the same as the main analysis where New York/Newark are included—with similar standardized coefficients and statistical significance.

RESULTS

Table 1 provides descriptive statistics for the variables used in the structural equation model. Over the 29-year study period of the 100 urban areas included in the sample, there were on average 4.73 annual motor vehicle fatalities per 100,000 persons with a range of 0 to 21.3 per 100,000. The share of mass transit miles traveled, relative to motor vehicle miles traveled, on a daily basis was 2 % with a range of 0 to 29 % indicating that mass transit travel comprises a small proportion of daily travel behavior in most cities. The price of gas was on average US\$1.59 with a range of US\$0.93 to US\$3.84 over the study period. The cost of congestion to the

TABLE 1 Description of the study sample: 100 metropolitan areas in the USA with any mass transit, 1982–2010

	Mean	Standard deviation	Min	Max
Precipitation, inches	3.36	2.44	0.45	39.01
Temperature, Fahrenheit	55.98	8.25	33.9	79.3
Gas prices, US\$	1.59	0.67	0.93	3.84
Cost of congestion, average commuter, US\$	411.87	329.41	6.41	2,197.15
Share of annual mass transit miles traveled per capita, %	2.01	2.86	0	29.16
Road fatalities per 100,000 population, #	4.73	3.56	0	21.3

Sources of data: Fatality Accident Reporting System, Texas Transportation Institute (TTI) urban mobility report, Census Bureau, and National Oceanic and Atmospheric Administration. *N*=2,900

average auto commuter was US\$411.87 with a substantial range over time and across cities of less than US\$7 to US\$2,197.

Figure 1 provides the standardized coefficients for the structural equation model. The detailed results from the analysis can be found in Table 2. The model fit was good as indicated by the model fit indices (RMSEA=.04; SRMR=.02). The coefficient of determination was 0.72 suggesting that our model explained a majority of the variance for the outcome. See Table 3 for a complete list of the model fit statistics. The primary finding from the structural equation model was that, after accounting for climate, year, and the economic costs of driving, an increasing share of mass transit miles traveled per capita was associated with a lower motor vehicle fatality rate ($\beta=-.15$, standard error (SE)=.02). The costs of congestion to the average commuter ($\beta=.43$, SE=.02) and gas prices ($\beta=.15$, SE=.03) were positively associated with increasing the share of mass transit miles traveled. The economic costs of driving increased over time, while both the fatality rate ($\beta=-.26$, SE=.02) and the share of mass transit miles traveled ($\beta=-.42$, SE=.03) decreased over time. Increasing temperature was associated with a

FIG. 1 Standardized coefficients for the structural equation model. Sources of data: Fatality Accident Reporting System, Texas Transportation Institute (TTI) urban mobility report, Census Bureau, and National Oceanic and Atmospheric Administration. *N*=2,900, maximum likelihood estimation method.

TABLE 2 Structural equation model: standardized coefficients, standard errors, and statistical significance statistics

	Standardized coefficient	Standard error	P value
Share mass transit <—			
Congestion cost	0.43	0.02	0.00
Gas cost	0.15	0.03	0.00
Year	−0.42	0.03	0.00
Precipitation	0.19	0.02	0.00
Temperature	−0.08	0.02	0.00
Constant	49.87	3.18	0.00
Fatalities per 100k <—			
Share mass transit	−0.15	0.02	0.00
Year	−0.26	0.02	0.00
Temperature	0.27	0.02	0.00
Precipitation	−0.04	0.02	0.04
Constant	32.66	1.94	0.00
Congestion cost <—			
Year	0.57	0.01	0.00
Constant	−66.83	1.37	0.00
Gas cost <—			
Year	0.74	0.01	0.00
Constant	−85.91	0.86	0.00
Variance for error			
Mass transit	0.83	0.01	
Fatalities	0.82	0.01	
Congestion cost	0.67	0.01	
Gas cost	0.45	0.01	
Congestion, gas	−0.07	0.02	0.00

Sources of data: Fatality Accident Reporting System, Texas Transportation Institute (TTI) urban mobility report, Census Bureau, and National Oceanic and Atmospheric Administration. *N*=2,900, maximum likelihood estimation method, observed information matrix standard errors

higher fatality rate ($\beta=.27$, $SE=.02$), while higher levels of precipitation were associated with lower fatality rates ($\beta=-.04$, $SE=.02$). All paths shown in Fig. 1 were statistically significant.

DISCUSSION

Our study examined the magnitude of the relationship between motor vehicle fatalities and mass transit use. Motor vehicle injuries and deaths are considered a worldwide problem and, certainly, one of the winnable public health battles in the USA.^{3,35} We used structural equation modeling to assess the complex relationship between mass transit use and motor vehicle fatalities. This analytic approach allowed us to account for several complicating factors including the trend toward lower motor vehicle fatalities, seasonal variations in travel behavior, the relationship between the economic costs of driving and mass transit use, and the relationship between congestion and mass transit use. We found that increased use of mass transit was associated with fewer fatalities from motor vehicle crashes after accounting for climate and the economic costs of driving. Therefore, reduced traffic deaths may be counted among the benefits of mass transit use in addition to already

TABLE 3 Model fit statistics for structural equation model

Fit statistic	Value	Description
Likelihood ratio		
chi2	62.17	model vs. saturated
$p > \text{chi2}$	0.00	
chi2_bs	4578.06	baseline vs. saturated
$p > \text{chi2}$	0.00	
Population error		
RMSEA	0.04	Root mean squared error of approximation
90 % CI, low	0.03	RMSEA lower bound
90 % CI, high	0.05	RMSEA upper bound
pclose	0.88	Probability $\text{RMSEA} \leq 0.05$
Information criteria		
AIC	164395.56	Akaike's information criterion
BIC	164491.12	Bayesian information criterion
Baseline comparison		
CFI	0.99	Comparative fit index
TLI	0.98	Tucker-Lewis index
Size of residuals		
SRMR	0.02	Standardized root mean squared residual
CD	0.72	Coefficient of determination

reported benefits such as economic development, reduced traffic congestion, and lower emissions.¹ Moreover, mass transit could also be considered a public health policy to consider among the many options to reduce motor vehicle fatalities in addition to already well-established policies that work toward improving vehicle safety, driver behavior, and law enforcement.

Our results should be interpreted within the context of several limitations. First, our data are limited to the use of mass transit in 100 major cities, which means this study cannot be interpreted as representative of the entire USA. One strength of the TTI data was measures of the economic costs of driving, which is a critical factor when people make decisions about the mode of travel. However, TTI did not have data on the cost of mass transit, which is also a critical factor in the decision process. We expect that the cost of mass transit would be weighed against the cost of driving when deciding whether and how much one would use mass transit. However, the pricing structure of mass transit is complex because the base cost may vary by city depending on the number of stops or based on the number of rides. Finally, our model would be stronger if there was historical data at the city level for number of fatalities from mass transit, although aggregate data from the Bureau of Transportation Statistics estimate there are approximately 150 per year for the USA and that many of these are caused by commercial trains hitting pedestrians or cars.⁴

CONCLUSION

Increasing the share of mass transit miles traveled, relative to motor vehicle miles traveled, may be an effective public health intervention to reduce motor vehicle fatalities in cities. Transportation policies should encourage the use of existing mass

transit systems, potentially incentivize the development of new mass transit services, and lower incentives to drive by increasing the economic cost of driving in areas with available—and oftentimes underutilized—mass transit services.

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