The American Story of Inequitable Road Safety Outcomes

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ABSTRACT

How equitable are our road safety outcomes? The differences along the urban-rural divide are fairly well known, but less is known about differences along socio-demographic and socioeconomic spectrums. This research considers these questions through the spatial analysis of over 950,000 road fatalities in the U.S. that took place over the course of a 24-year period (1989 – 2012). The results suggest widespread disparities by population density and income level but less by race/ethnicity. A number of factors likely contribute to these results, including differences in emergency medical care as well as differences in vehicle safety features; however, land use and transportation differences are also seen as major contributing factors.

INTRODUCTION

Popular perception has long viewed urban areas as far more dangerous places to live than rural areas. The data, however, more often than not tells another story. With respect to gun violence, the risk of an urban child gun death is not statistically different than the risk for children in rural areas (Carr et al. 2010). When talking about the overall population, the rate of intentional firearm deaths was not any higher in urban counties than in rural (Nance et al. 2004). While urban areas found a higher homicide rate, this was balanced out by a much higher suicide rate in rural areas. Moreover, violent crime rates have been dropping in cities at a much faster rate than in rural areas (BJS 2000). Even with our most recent military conflicts, the casualty rate for troops from rural areas was significantly higher than the death rate for those military members from urban areas (Curtis and Payne 2010). In terms of overall mortality, however, the largest contributor to the urban-rural divide in the United States can be found in our transportation system.

The level of urbanization in the U.S. is at a higher level than ever before (U.S. Census Bureau 2010). In 2012, just over 80% of U.S. the population lived in urban areas; yet, only 46.5% of our road fatalities took place in urban areas, a number that includes both pedestrian and bicyclist deaths as well as vehicle occupants. While striking, this statistic does not even begin to tell the whole story, particularly because the Census definitions of “urban” and “rural” result in a binary depiction of a more complex continuum. Beyond the urban-rural differences, there are also significant equity concerns, including potential disparities along race/ethnicity and economic status. This research delves into these issues through the spatial analysis of over 950,000 road fatalities in the U.S. that took place over the course of a 24-year period (1989 – 2012). For this timespan, we geocoded the entire Fatality Analysis Reporting System (FARS) database, separating out vehicle occupants from pedestrian/bicyclist fatalities, and analyzed crashes both in terms of where the crash occurred as well as by the home zip code of the driver (NHTSA 2014). By distinguishing between where the crash happened and where those involved were likely from allowed us to better understand the impact of our transportation system on various populations. After a brief historical background looking at the U.S. approach to understanding and improving urban-rural safety problems, we further detail the data and methodologies before presenting our results.

BACKGROUND

Road fatalities in the United States went from being a non-factor at turn of the twentieth century to being grouped among the top ten leading causes of death a generation later in 1926 (CDC 2000). Quickly becoming an issue of national concern, the response to this issue was beautifully captured in the book *Fighting Traffic* by Peter Norton (Norton 2008). Prior to the 1920s, streets were – as Norton points out – the primary public space in most cities and a place where children could play without much fear of being run over. Hundreds of pedestrian deaths over the course of the 1920s left the public looking for somebody to blame, and the initial answer seemed to be the drivers. The campaign to fight this perception – and the larger battle of who streets were for – was well-organized and well-funded. It was not long before the term "*jaywalking*" was coined and people were cordoned off to sidewalks and crosswalks (Norton 2008). The streets had been given over to cars, in large part due to safety concerns.

Despite such a momentous shift in policies and attitudes, the road fatality rate continued to rise and rise. At a 1949 conference on road safety, President Truman spoke about the continuing "*frightful slaughter on our streets and highways*," citing the fact that the number of road fatalities in 1948 was more than double the number of troops lost during the six-week Normandy campaign (Weingroff 2003). Truman went on to highlight the 429 road fatalities that had occurred on Memorial Day of the previous year.

> "*Now, if a town had been wiped out by a tornado or a flood or a fire and killed 429 people, there would be a great hullabaloo about it. We would turn out the Red Cross, and we would have the General declare an emergency... Yet, when we kill them on the road…, we just take it for granted. We mustn't do that*" (Weingroff 2003).

The safety report emanating from that 1949 conference called for the "*use of engineering principles and techniques to eliminate or reduce physical hazards and to promote the safe control of traffic movements*" (Weingroff 2003).

By 1951, the number of Americans killed in car crashes had surpassed one million; not long thereafter, the number of U.S. traffic deaths eclipsed the total number of Americans killed in all U.S. wars combined, including the America Revolution (Weingroff 2003). However, the fatality numbers were beginning to decline in urban areas, and by 1958, pedestrian deaths had dropped by a third. While these improvement were more than offset by increased road fatalities across the rest of the county, the approaches to "*engineering principles*" that the U.S. decided to take in trying to improve road safety were decidedly rural, such as the clear zone concept.

The clear zone is the area where fixed-object hazards are minimized and has been standard design practice since the 1967 AASHO publication of *Highway Design and Operational Practices Related to Highway Safety*, which cited the need for a 6-meter (19.7') clear zone (AASHO 1967).

The recommended lateral clearance later increased to 9-meters (29.7') and explicitly included both rural and urban locations (AASHTO 1970). The clear zone concept was in part an outcome of the Congressional road safety hearings held in 1966 to combat the continuing rise in fatalities and injuries on the roadways. The hearings took place over the course of more than a year and were highlighted by two key figures: Ralph Nader, who had just published *Unsafe at Any Speed* the year before; and Kenneth Stonex, a General Motors engineer (Weingroff 2003). Nader's testimony focused on the need for a new passive safety paradigm based on the idea that while crashes are inevitable, injuries are not (Dumbaugh 2005). The previous ten years had focused on public safety campaigns; Nader's point was that engineering measures – thorough better vehicle and road design - were far easier to influence than the behavior of millions of drivers (Nader 1965). Stonex worked at the GM Proving Grounds, a 65-mile test track in Milford, Mighigan. His research suggested three keys to better road safety: access management; one-way traffic; and fewer roadside obstacles (Weingroff 2003). Focusing in on the last point, Stonex reported that removing all fixed objects from within 100 feet of the road, such as at the Proving Grounds, would make it "*pretty hard to commit suicide on*" (Weingroff 2003). Stonex goes on to say that:

> "*This is the real transportation problem that remains to be approached. What we must do is to operate the 90% or more of our surface streets just as we do our freeways… [converting] the surface highway and street network to freeway and Proving Ground road and roadside conditions*" (Weingroff 2003, Dumbaugh 2005).

Despite clear data showing that urban places were safer than rural areas as far back as the 1950s, this quote represents the thinking that has guided design over the last fifty years (Dumbaugh 2005). Part of the rationale for this shift in mentality derived from the fact that limited access highways are far safer on a per-mile basis than most other street types. Analyzing safety based upon such a mileage-based fatality rate, however, is a biased measure. For instance, consider the following comparison:

City A	City B
Road Fatalities: 8	Road Fatalities: 8
Vehicle Miles Traveled: 2 million	Vehicle Miles Traveled: 1 million

City A has a fatality rate of 4 per million miles traveled and City B has a fatality rate of 8 per million miles traveled. Given such numbers, it would understandable for one to opt for living in City A. But what if City A has a population of 50,000 and City B a population of 100,000? With population as the exposure, the fatality rate of City A becomes 16 per 100,000 population and City B becomes 8 per 100,000 population. Given those numbers, City B is markedly safer and the clear choice.

Figure 1 depicts these two road fatality rates for the U.S. from 1900 through 2012. With the drastic increase in vehicle miles traveled over this time period, the improvement to the mileage-based fatality rate is not a big surprise. The population-based metric tells a bit of different story, and one that is more illustrative of the health-impact of transportation. As a result, the data we present in this paper is based on the fatality rate per 100,000 population.

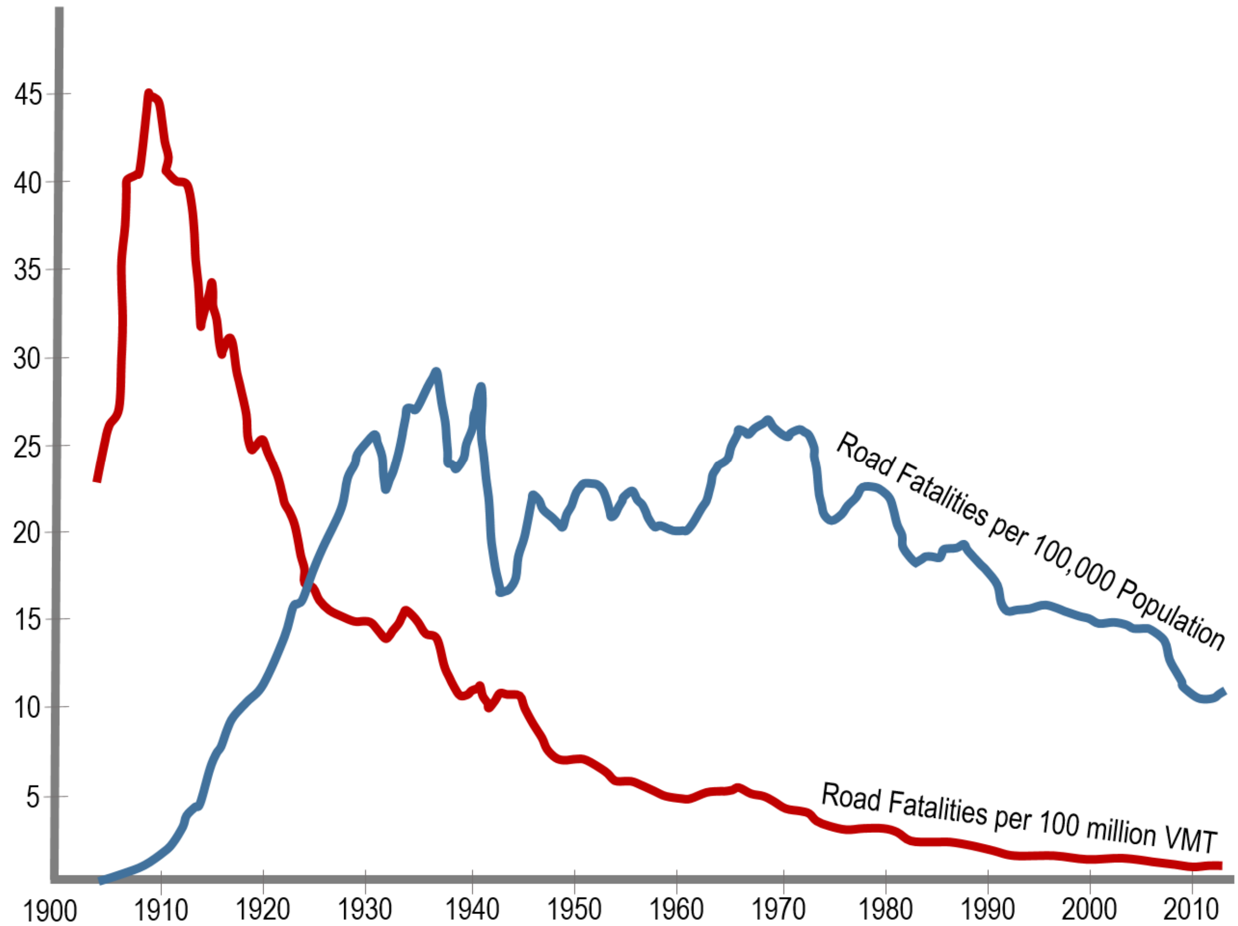

Figure 1 - Road Fatality Rates (1900 - 2012), data derived from (FHWA 2007, 2014, Advocates for Highway and Auto Safety 2004, NHTSA 2014, Thomas, Fisher, and Hirsch 2002, CDC 2014)

The next section details the data and methodology.

DATA & METHODS

A significant data collection effort was needed to understand the equity issues in road safety. The initial idea was to geocode as much FARS crash data as possible and assemble the most appropriate socio-demographic and socioeconomic data available. Given that the driver's crash record included his/her home zip code, we focused on the zip code as the unit of analysis.

Crash Data

Fatal crash data from the years 1989 through 2012 was retrieved from the Fatality Analysis Reporting System (FARS), and each crash record was geocoded into a GIS database. Fatal crashes occurring post approximately 2001 were typically coded using latitude and longitude information. Fatal crashes up until around 2001 were geocoded to the highest degree of accuracy possible based on the location information provided by FARS. Geocoding was conducted using ESRI Online geocoding in combination with the online mapping services Mapquest and Google. With each step, a subset of geocoded crashes were tested for accuracy and/or any systematic errors; if errors were found, the crashes would be re-geocoded using another technique. The overall success rate was: 97.9%.

The total number of successful geocoded fatal crash locations over the 24-year period included 808,982 vehicle occupant deaths and 142,859 deaths of those not within a motor vehicle (e.g. pedestrians and bicyclists). The total number of fatalities analyzed was 951,571 out of a 971,606 total fatalities (i.e. 20,035 or 2.1% of the total fatalities were not geocoded or included in the analysis). Most of the fatalities not analyzed seemed to have taken place in more rural areas.

Socio-demographic and Socioeconomic Data

In order to analyze the crash data with respect to socio-demographic and socioeconomic differences in income, race/ethnicity, and age, we collected data from the 2012 American Community Survey (ACS) as well as Census data from the National Historical Geographic Information System (nhgis.org) for the years 1990, 2000, and 2010. We analyzed the entire crash database against the 2012 ACS data and also conducted an analysis where we linked each crash year to the nearest temporal decennial Census year (e.g. 1996 FARS data is compared to 2000 Census data). The trends with each set of results were remarkably similar; as a result, we focus the results presented in this paper on the 2012 ACS data for the sake of clarity. The 2012 ACS included 32,653 populated zip codes.

Methods

We counted occupant deaths in two manners: i) by geocoded location (i.e. where the crash happened); and ii) by summarizing the driver's zip code (i.e. where the person was likely from). This was done in order to differentiate between where fatal crashes physically took place and who is actually being impacted by these fatalities.

With the first step, each of the 951,571 geocoded road fatalities was counted and summed at the zip code level of geography in GIS. For the sake of comparison, we kept the vehicle occupant fatalities separate from those that were likely to be pedestrians or bicyclists.

The second step involved attributing the driver's home zip code (that is available within the vehicle tables of the FARS database) to each vehicle occupant death. After linking the appropriate zip code to the person table, we summarized the total number of fatalities by zip code and joined the summary table to the zip code GIS file. The result represents the risk to an individual from that zip code under the supposition that the vehicle occupant killed was likely from the same zip code as the driver.

Other than gender and age, the FARS data set does not include socio-demographic information about those killed. In order to make this connection, we postulated that road fatalities took place in similar percentage to the racial/ethnic composition of that zip code. For instance if a particular zip code with 100 fatalities over the 24-year period was 70% white and 30% black, we assumed that 70 of those fatalities were white residents and 30 were black. This was done based on the driver's home zip code for vehicle occupant deaths and on crash location for pedestrian and bicyclist fatalities. For the sake of the income analysis, we also attributed the median household income to all the fatalities associated with that zip code. This again was based upon the driver's home zip code for vehicle occupant fatalities and by crash location for pedestrian and bicyclist deaths.

The fatality rates presented were calculated as the number of fatalities per year per 100,000 population. During our preliminary analysis, we also found that averaging the fatality rates resulted in noticeably different results than if the fatality rates were weighted by population. Take for example one zip code with 100,000 residents and a fatality rate of 8 deaths per year per 100,000 population and a second zip code with only 5,000 residents but a fatality rate of 15 per year per 100,000 population. Simply averaging the two would result in a fatality rate of 11.5, which would not be representative of reality. As a result, we weighted the results by population. In this case, the average weighted fatality rate for these two zip codes would be 8.33. The fatality rate results presented in the next section are all population-weighted averages.

RESULTS

The results are presented in Table 1 and Table **2**. Table 1 depicts the fatality rates for urban vs. rural, household income, and by population density. Table 2 shows the results by race/ethnicity and then divided into urban and rural for each category. The number of zip codes of each category is represented by the n value. The vehicle occupant results are also color coded by relative level of safety with:

- Green = 0 to 5 fatalities per year per 100,000 residents;
- Yellow = 5 to 10 fatalities per year per 100,000 residents;
- Orange = 10 – 15 fatalities per year per 100,000 residents; and
- Red = 15+ fatalities per year per 100,000 residents.

Green is on the order of some of the safest countries in the world such as the Netherlands, which has a fatality rate of 4.0 road fatalities per 100,000 residents (OECD 2011). The current road fatality rate for the U.S. is approximately 10.7 per 100,000 residents.

The initial results in Table 1 show a stark comparison between the health impacts of the transportation system on those living in urban areas versus those living in rural. This was true when aggregating by crash location as well as by driver's zip code. Interestingly, the pedestrian/bicyclist fatality rates are similar in urban and rural areas, despite the likelihood of a large exposure difference (i.e. higher rates of walking and bicycling in urban areas).

The population density results follow a similar trend to the urban/rural results but do so with an even greater order of magnitude. Overall, those living in the sparser locations find a fatality rate more than 6X greater than those living in the densest areas. This equates to our more urban and dense areas being almost as safe as some of the safest developed nations in the world and our more rural areas being akin the most dangerous developed countries in the world. The trend when looking at the results from most sparse to most dense is remarkably strong and tends to show greater safety with greater densities. Also, the difference in pedestrian/bicyclist fatality rates are again far more similar than one might expect.

Considering the results by household income generated much bigger differences between the crash location results and those aggregated by the driver's zip code. For instance with the wealthiest zip codes, the fatality rate exceeded 19 per 100,000 residents when considering where the crash occurred but less than 6 when looking at the driver's zip code. This suggests that while there might be high traffic fatality numbers in our wealthiest neighborhoods, they rarely involve somebody from that neighborhood. These wealthier zip codes tended to be near the downtowns of major cities, so the pedestrian/cyclist fatality rate was also exceedingly high. Whether the pedestrians or cyclists killed were from the wealthier neighborhoods or not is harder to judge given the fact that many of these were downtowns of major cities. On the other hand, the poorest zip codes also saw a relatively high pedestrian/cyclist fatality rate. Overall, the income trends suggest – particularly when focusing on the driver's zip code results, which are intended to be more representative of the road safety impact on the local population – tremendous disparities along income thresholds.

Table 2 first shows the results by race/ethnicity. Other than the zip codes with the most Asian residents tending to be safer, the trends for the other categories were not as apparent. The most noticeable differences were again in the rural versus urban for each category. Overall, the rural residents had fatality rates 2X to 3X those of their counterparts in almost every race/ethnicity category. The difference in pedestrian/bicyclist fatality rates between urban and rural areas was not significant.

Table 1 - Fatality Rates

		Vehicle Occupant Fatality Rate		Pedestrian/ Bicyclist Fatality Rate
	n	Crash Location	Driver's Zip Code	Crash Location
Urban vs. Rural				
Urban	8,404	6.74	7.79	1.99
Rural	24,249	17.41	15.44	1.82
Population Density (people / sq. mi.)				
0 - 50	13,436	31.35	24.49	2.22
50 - 200	7,107	18.82	17.01	1.81
200 - 500	3,132	12.32	11.55	1.65
500 - 1,000	2,097	8.73	8.96	1.58
1,000 - 3,000	3,362	6.91	7.78	1.70
3,000 - 5,000	3,362	5.89	7.73	2.04
5,000 - 7,000	1,649	5.56	7.46	2.41
7,000 - 9,000	712	4.33	6.33	2.25
9,000 - 12,000	360	4.61	6.00	2.69
12,000+	540	4.96	4.12	2.58
Household Income				
0 - 20k	1,193	22.17	13.03	5.69
20k - 40k	8,980	15.31	14.98	2.83
40k - 80k	19,419	10.48	10.55	1.74
80k - 120k	2,541	5.51	5.62	1.22
120k - 160k	400	5.21	4.28	1.23
160k - 200k	82	5.53	4.12	0.87
200k+	38	19.16	5.64	10.84

Fatality Rate (fatals/100k pop)	Color Coding
0 - 5	Green
5 - 10	Yellow
10 - 15	Orange
15+	Red

Table 2 - Fatality Rate by Race/Ethnicity & Urban/Rural

Race / Ethnicity	n	Vehicle Occupant Fatality Rate: Crash Location	Vehicle Occupant Fatality Rate: Driver's Zip Code	Pedestrian/ Bicyclist Fatality Rate: Crash Location
% White				
0 - 10%	486	9.56	11.61	3.34
10 - 30%	773	8.84	9.04	2.99
30 - 50%	1,433	9.27	9.06	2.69
50 - 70%	2,971	9.21	9.53	2.30
70 - 90%	8,064	9.54	9.81	1.76
90+%	15,186	14.46	13.40	1.42
% Black				
0 - 5%	23,572	11.69	11.28	1.63
5 - 10%	2,672	8.59	9.00	1.82
10 - 20%	2,451	9.78	10.14	2.06
20 - 30%	1,277	10.46	10.70	2.25
30 - 50%	1,346	12.46	11.81	2.67
50+%	1,301	11.89	11.69	3.16
% Asian				
0 - 5%	29,447	12.85	12.52	1.95
5 - 10%	1,709	6.01	6.45	1.74
10 - 20%	951	4.91	5.42	1.91
20+%	546	4.42	4.66	2.08
% Hispanic				
0 - 5%	21,401	14.32	13.31	1.67
5 - 10%	4,268	9.51	9.47	1.80
10 - 20%	3,207	8.63	8.83	1.93
20 - 30%	1,338	8.70	9.10	2.23
30 - 50%	1,226	7.97	9.17	2.21
50+%	1,178	8.24	9.23	2.69

Urban	n	Vehicle Occupant Fatality Rate: Crash Location	Vehicle Occupant Fatality Rate: Driver's Zip Code	Pedestrian/ Bicyclist Fatality Rate: Crash Location
% White				
0 - 10%	174	7.14	9.36	2.99
10 - 30%	405	6.84	7.53	2.97
30 - 50%	733	6.47	7.18	2.58
50 - 70%	1,499	6.63	7.55	2.30
70 - 90%	3,383	6.33	7.61	1.72
90+%	2,002	8.05	8.86	1.33
% Black				
0 - 5%	4,030	6.21	7.30	1.64
5 - 10%	1,398	6.32	7.47	1.88
10 - 20%	1,204	6.99	8.07	2.04
20 - 30%	562	6.92	8.14	2.24
30 - 50%	559	8.12	8.44	2.66
50+%	643	8.61	9.60	3.11
% Asian				
0 - 5%	5,925	7.82	9.09	2.04
5 - 10%	1,253	5.47	6.12	1.80
10 - 20%	796	4.47	5.26	1.92
20+%	430	4.47	4.56	2.17
% Hispanic				
0 - 5%	3,358	8.13	8.55	1.66
5 - 10%	1,708	6.45	7.30	1.83
10 - 20%	1,496	6.01	7.08	1.95
20 - 30%	659	6.36	7.71	2.24
30 - 50%	615	5.80	7.67	2.25
50+%	561	6.30	8.14	2.72

Rural	n	Vehicle Occupant Fatality Rate: Crash Location	Vehicle Occupant Fatality Rate: Driver's Zip Code	Pedestrian/ Bicyclist Fatality Rate: Crash Location
% White				
0 - 10%	312	23.89	24.88	5.41
10 - 30%	368	21.89	18.93	3.12
30 - 50%	700	21.26	17.11	3.14
50 - 70%	1,472	16.77	15.36	2.31
70 - 90%	4,681	15.44	13.86	1.84
90+%	13,184	18.04	15.93	1.47
% Black				
0 - 5%	19,542	17.31	15.35	1.62
5 - 10%	1,274	14.56	13.04	1.68
10 - 20%	1,247	16.21	14.89	2.09
20 - 30%	715	18.10	16.24	2.25
30 - 50%	787	22.05	19.05	2.67
50+%	658	24.96	20.03	3.35
% Asian				
0 - 5%	23,522	18.31	16.25	1.85
5 - 10%	456	8.67	8.04	1.49
10 - 20%	155	9.00	6.88	1.75
20+%	116	6.38	5.45	1.34
% Hispanic				
0 - 5%	18,043	19.39	17.20	1.68
5 - 10%	2,560	15.03	13.38	1.77
10 - 20%	1,711	15.22	13.23	1.89
20 - 30%	679	15.42	13.08	2.21
30 - 50%	611	14.95	13.99	2.12
50+%	617	14.45	13.22	2.58

CONCLUSIONS

Now more than 65 years after President Truman spoke about inadequate road safety results and a lackadaisical attitude of the general public towards road deaths, it is hard to believe how little things have changed. With horrific car crashes a common occurrence on the nightly news, we continue to treat road fatalities as part of the cost of doing business. Unfortunately, all Americans are not bearing the costs of this problem equitably. Beyond the vast urban-rural divide, we find significant discrepancies across the population density spectrum as well as by household income. If the cost of doing business is people dying on the roads, it is noteworthy that those making the least money tend to be the most impacted.

A number of factors likely contribute to these results, including differences in emergency medical care as well as differences in vehicle safety features. Exposure is also another important issue, as cities tend to do a much better job of reducing vehicle miles traveled. As Lewis Mumford once wrote: "*a good transportation system minimizes unnecessary transportation*" (Mumford 1963). As such, transportation and land use design differences are also likely to play a major role. While rural designs may help facilitate longer travel distances at higher speeds, there is a significant mortality cost that comes with those advantages. On the other hand, more urban areas tend to be designed in a manner that directly counters the pervasive passive design mentality that emerged from the Congressional road safety hearings of the mid 1960s. Instead of continuing this passive safety paradigm of applying rural designs to more urban locations, perhaps it is now time to bring the safety lessons learned in more urban areas to those living outside the city.

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