URBAN STREET STRUCTURE AND SAFETY

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ABSTRACT

The high risk of injuries and fatalities in urban areas to pedestrians, bicyclists and commuters in access trips have been documented from all over the world. Unless walking, bicycling and access to public transport is made safer, it will be difficult to promote these modes. This paper reports the influence of urban structures and road layout on road traffic fatality rates. To obtain road fatality data for US cities, we used the Fatality Analysis Reporting System (FARS) files to obtain total number of fatalities for all cities for the years 2004-2008. We used the average fatalities per year per unit population of the city to estimate risk to road users. High fatality rate cities have rates that are greater by a factor of 3-6 compared to those with the lowest rates, and there is high variability in rates at all population levels. Twenty randomly selected cities with high and low rates were used for comparison of road layout details. Cities with higher crash rates have a higher proportion of crashes on roads that have 4 or more lanes, and cities with higher crash rates seem to have more crashes at mid-block. Urban form and street design patterns may have to be given much more importance to improve safety of pedestrians, bicyclists and transit users. Once we are able to design safer cities, we can then promote cleaner modes of travel more easily. Therefore, urban safety becomes a necessary condition for addressing global warming.

Keywords: Traffic safety, urban planning, urban safety

INTRODUCTION

International road traffic fatality rates

Figure 1 shows the country reported road traffic injury (RTI) fatality rates per 100,000 persons plotted against national per-capita income for 178 countries, and Figure 2 the WHO estimates for the same countries (WHO 2009). It is widely recognised that fatality statistics suffer from under reporting in many countries (Peden et al. 2004). A correction for this was attempted by WHO by adjusting the fatality figures for a 30 day period for death after the crash. They also used a negative binomial regression model for estimating fatalities for each country by accounting for income, exposure, risk factors and strength of the health system (details: www.who.int/ violence_injury_prevention/road_safety_status/2009/). Only 85 (48%) of the countries reported fatality rates within 5% of the WHO estimates, 80 countries (45%)

reported much lower numbers, with 55 reporting numbers less than half that estimated by the WHO. More high-income countries seem to have reported rates close to WHO estimates than low-income countries.

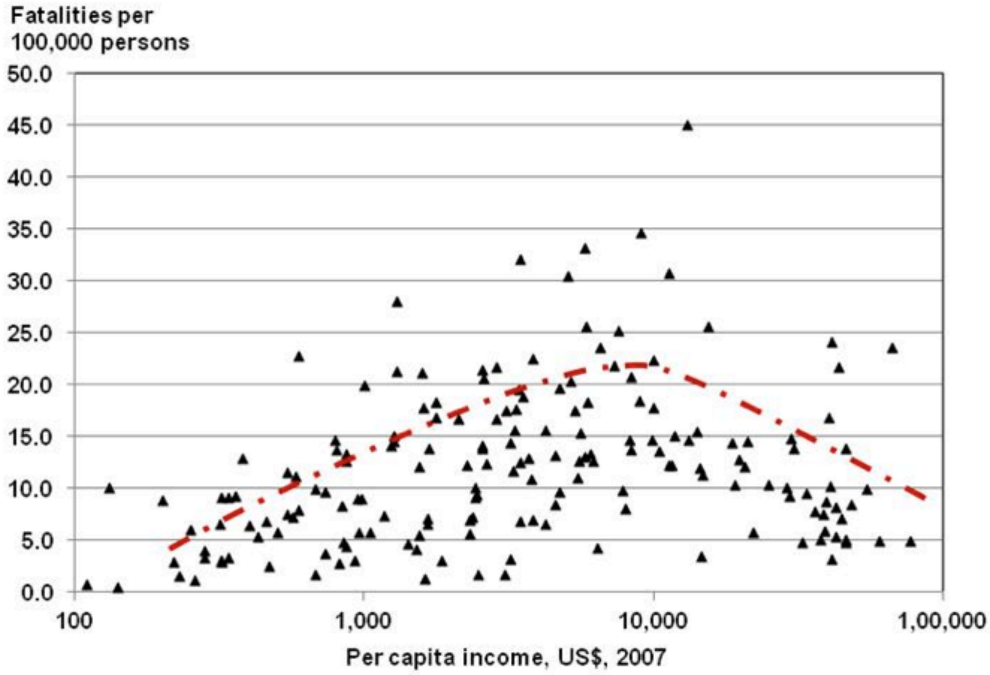

Figure 1 - Road traffic fatalities per 100,000 persons for 178 countries, self reported for 2007 (Source: WHO 2009)

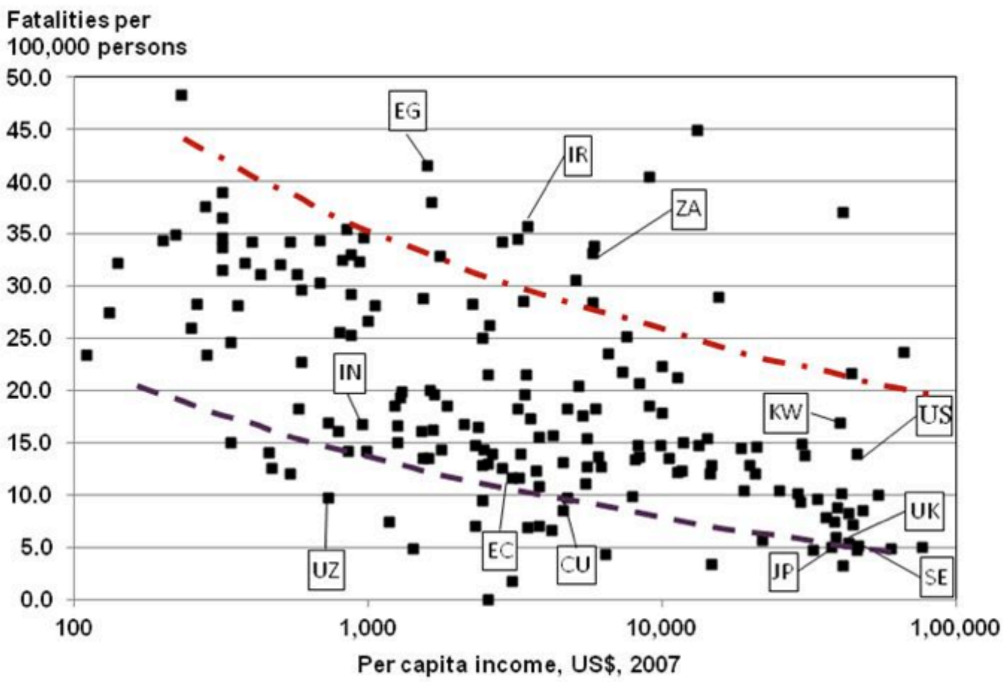

Figure 2 - WHO estimates for road traffic fatalities per 100,000 persons for 178 countries, 2007 (CU-Cuba, EC-Ecuador, EG-Egypt, IN-India, IR-Iran, JP-Japan, KW-Kuwait, SE-Sweden, UZ-Uzbekistan, ZA-South Africa) (Source: WHO 2009)

Figure 1 shows that national RTI fatality rates per 100,000 persons (reported) generally seem to increase with income initially and start decreasing after per capita incomes exceed US$ 10,000 per year. On the other hand, the trend of the country RTI fatality rates from WHO estimates is seen to decline steadily with income (Figure 2). Some high-income countries like Kuwait and USA have higher rates than middle and low-income countries like Ecuador and Cuba. However, at all income levels, countries with the highest fatality rates have values 3-5 times higher than the ones with low rates. For example, among high-income countries, USA has a fatality rate that is three times greater than that in Japan and UK. Among middle income countries Iran and South Africa have rates three times greater than Ecuador and Cuba, and among low-income countries Egypt has a rate four times greater than in Uzbekistan.

The trends shown by the WHO estimates for RTI fatalities are contrary to the conventional wisdom that fatality rates must first rise with income and can only decline after countries reach average incomes greater than US$ 10,000. This understanding was based on the assumption that risk of fatality per vehicle always decreases with increase in vehicles per capita, and the number of vehicles per capita always increases with increases with income, a belief supported by reported data as projected in Figure 1. This understanding incorporates two theoretical weaknesses – that risk will always be high at low incomes, and that issues of underreporting have not been accounted for. Data presented in Figure 2 indicates that when estimates are made to correct for underreporting, rates of a larger number of countries in the low and middle-income group see an increase than countries in the high-income group. This is why Figure 2 indicates a different trend than that shown in Figure 1. If the estimates arrived at by the WHO are closer to the truth, then we get a different understanding of international trends.

Up to now the traditional understanding has been used to make future projections for RTI fatalities in different countries. For example, a World Bank sponsored study estimates that RTI fatalities in India will only start reducing in 2042 (Figure 3) when the per-capita income of India exceeds US$ 8,000 (1985 international US$) (Kopits and Cropper 2005). If the trends indicated by WHO estimates are closer to the truth, then such projections need not have much validity.

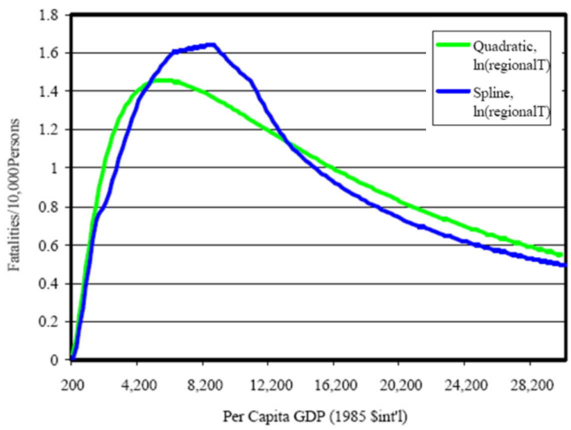

Figure 3 - Estimates for RTI fatalities per 100,00 persons and country per capita income, log-linear regional time trends (Kopits and Cropper, 2003)

The new estimates suggest that there may be other factors at work that influence road safety issues than just road design, vehicle design and enforcement. Otherwise, there should not be such great differences between countries at similar income levels. If we assume that the knowledge base, availability of funds, quality of roads and cars is roughly similar in the high-income countries in Western Europe and North America, then we should not expect differences in rates that vary by a factor of 3. This could be partly explained by differences in travel per day (affecting exposure) and levels of enforcement.

To see whether such differences also exist among large cities where enforcement levels are stricter, we examined data for 56 cities around the world to determine overall trends. To understand details of road traffic crashes and associated street structure issues we analysed details of fatal road traffic crashes for cities in USA where such details are available in the public domain.

METHODS

Urban road traffic fatality rates – international data

Road traffic fatality data were collected for 56 cities around the world for the period 2000 to 2003 from the following sources: official internet sites of respective cities/nations, journal publications in the same period, and official city traffic and accident reports. An attempt was made to obtain data for cities representing a wide spectrum of per-capita incomes. Road user fatalities per million population has been used as the index of the probability of an individual dying due to RTI in each city. This study attempts to look at trends and the health risk of individuals over a life span. Therefore, other indices like deaths per 10,000 vehicles or deaths per passenger km have not been used, as these do not give an indication of road traffic injuries as a health problem (Mohan et al. 2006). Since the number of trips taken in a city is proportional to its population, this index is also proportional to the risk of fatality per trip for that city. This is the risk that individual road users must minimize if they have to maximize their life spans. The risk per trip is the experience that individuals approximate internally for decision-making regarding mode choice (Koornstra et al. 2002). We have not differentiated data sets for different countries by definitions of death based on time elapsed after the crash. This is because research studies show that 65 to 75% of fatal crash victims die before reaching the hospital in most countries (Lai et al. 2006; Peden, Scurfield, Sleet, Mohan, Hyder, Jarawan, & Mathers 2004). Therefore, the error introduced by not accounting for time of death will generally not exceed thirty per cent, whereas the difference between different RTI rates between different countries and cities can exceed three hundred per cent.

Road traffic fatality trends for cities in USA

To eliminate the issue of variations in income among cities we examined the experience of cities within the USA. We expect that variations in enforcement, technology, funds and ‘culture’ would be less among US cities than comparing cities across nation states.
To obtain RTI fatality data for US cities, we used the Fatality Analysis Reporting System (FARS) (http://www-fars.nhtsa.dot.gov/Main/index.aspx) files to obtain total number of fatalities for all cities for the years 2004-2008. The variables included were: fatalities by road user type, location of fatalities by class of road, number of lanes at location of the crash, and whether the crash occurred at a junction or mid block. Population data for all cities was obtained from the US Census Bureau data files (www.census.gov). We used the average fatalities per year per unit population of the city to estimate risk of road users.
Fatality rates in US cities were examined considering the place where the death occurred, by three different categorizations:

1. Number of lanes of the road: 1-2 lanes, 3 lanes, 4 lanes, and 4+ lanes (4 categories)
2. Junction characteristic: intersection, midblock, other (3 categories)
3. Type of road: rural, urban interstate/freeway/expressway (IS/FW/EW) , principal arterials (PA), main arterials (MA), collector/local roads, unknown (6 categories)

In the absence of detailed traffic modal share, speed and crash information, we grouped cities into 5 population groups:

1: ≤25,000 (n=437)
2: >25,000, ≤100,000 (n=1369)
3: >100,000, ≤400,000 (n=235)
4: >400,000, ≤1,000,000 (n=35)
5: >1,000,000 (n=9)

Then we randomly selected two cities with highest fatality rates and two with lowest rates in each group. The list of these 20 cities is given in Table 1. Out of the randomly selected cities shown in Table 1 we used the high and low crash cities for comparison.

Table 1 - List of 20 cities in USA selected randomly stratified by population stratum and 2 cities each for high and low RTI fatality rates

Population stratum	Fatality rate group	Rate per 100,000	City	State
1: ≤25,000 (n=437)	Low: ≤10 per 100,000	0.0	West & East Lealman	Florida
		0.0	Herndon	Virginia
	High: >120 per 100,000	171.2	Tarpon Springs	Florida
		252.8	Seal Beach	California
2: >25,000, ≤100,000 (n=1,369)	Low: ≤10 per 100,000	0.0	Castro Valley	California
		5.6	Keizer	Oregon
	High: >120 per 100,000	277.5	Columbus	Indiana
		201.5	Tupelo	Mississippi
3: >100,000, ≤400,000 (n=235)	Low: ≤10 per 100,000	0.0	Enterprise	Nevada
		0.0	Spring Valley	Nevada
	High: >120 per 100,000	205.1	Amarillo	Texas
		130.1	Downey	California
4: >400,000, ≤1,000,000 (n=35)	Medium: ≤120 but >10 per 100,000	69.1	Omaha	Nebraska
		92.5	Long Beach	California
	High: >120 per 100,000	153.1	Oklahoma City	Oklahoma
		204.5	Jacksonville	Florida
5: >1,000,000 (n=9)	Medium: ≤120 but >10 per 100,000	79.3	Chicago	Illinois
		93.2	Philadelphia	Pennsylvania
	High: >120 per 100,000	164.8	Dallas	Texas
		178.8	Phoenix	Arizona

RESULTS AND DISCUSSION

International data

Fatalities per unit population have been plotted against the per capita income in US dollars to examine the general influence of the economy in determining the average risk of an individual dying due to an RTI in each city. In the graph, the airport code for each city is used to provide a unique identifier (Appendix 1). Figure 4 shows road traffic fatalities per million population for 56 cities around the world. These data show that there are wide variations across income levels and within similar incomes levels. The risk varies by a factor of about 20 between the best and the worst cities. Some characteristics are summarised below:

- Overall fatality risk in cities with very low per-capita incomes (less than USD 1,000) and those with high incomes (greater than USD 10,000) seems to be similar.
- There is a very high variability in fatality risk in middle income countries (USD 10,000-20,000)
- There is a great deal of variation even in those cities where the per capita income is greater than USD 20,000 per year.

These patterns appear to indicate that it is not sufficient to have the safest vehicle technology to ensure low road traffic fatality rates uniformly across cities in those locations. Even in low and middle-income countries, the absence of funds and possibly unsafe roads and vehicles does not mean that all cities have high overall fatality rates. Provision of safely designed roads and modern safe vehicles may be a necessary condition for low road fatality rates in

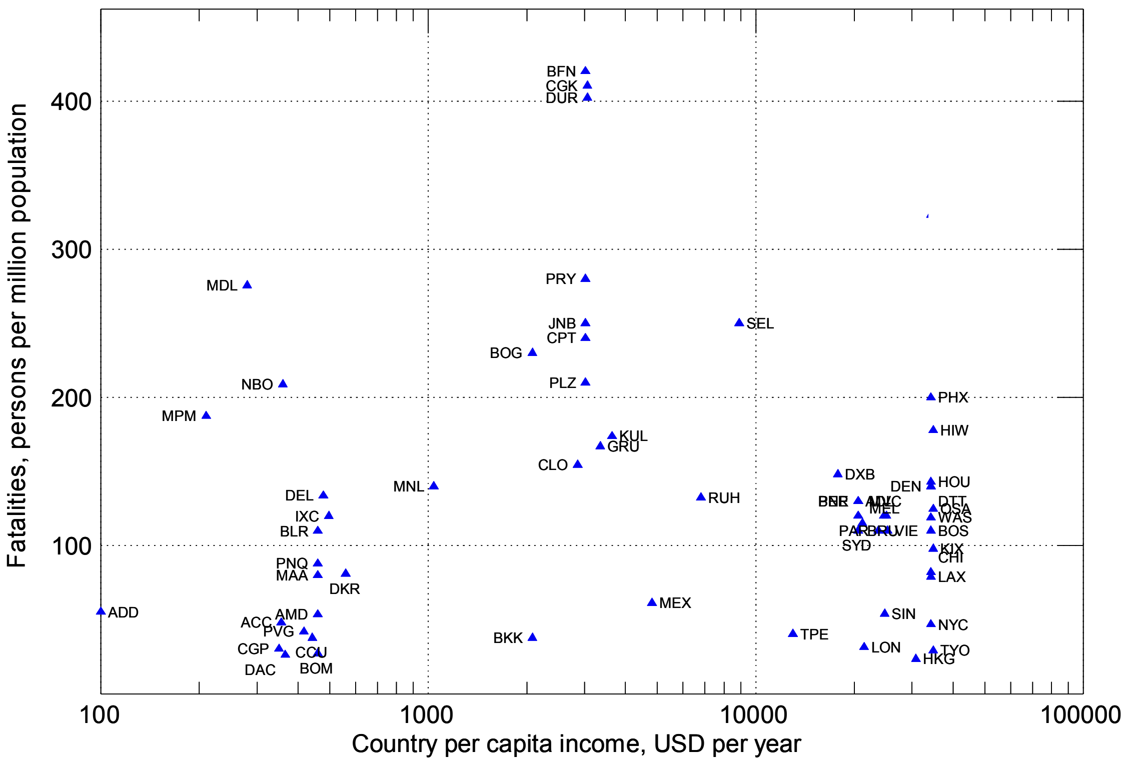

Figure 4 - Fatality risk in traffic crashes by city (city codes given in Appendix 1).

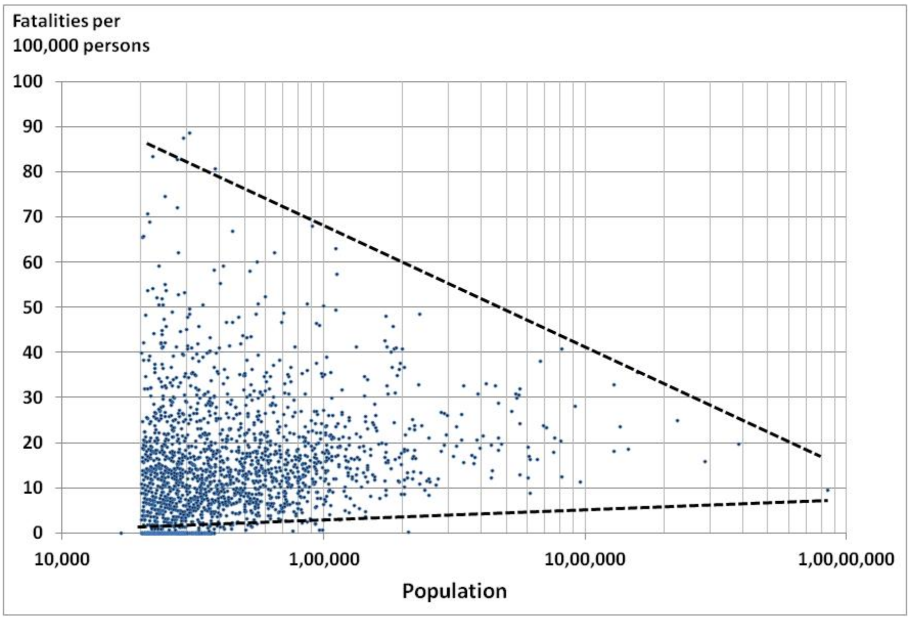

Figure 5 - Average RTI fatality rates per 100,000 persons (years 2004-2008) for 1,972 cities in USA with population > 20,000 persons

cities, but not a sufficient one. The fact that there are wide variations for overall fatality rates among high income cities, where availability of funds, expertise and technologies are similar, indicates that other factors like land use patterns and exposure (distance travelled per day, presence of pedestrians, etc.) may play an important role also. Vehicle speed is very strongly related to both the probability of a crash and the severity of injury – a 1% increase in average speeds can result in a 3 to 4% increase in fatalities (Peden, Scurfield, Sleet, Mohan, Hyder, Jarawan, & Mathers 2004). This may be the reason why some cities in middle-income countries have high fatality rates, because they have higher vehicle ownership than low-income countries and roads encourage unsafe speeds without adequate attention having been given to road safety. Similarly, cities that are considered to have greater traffic congestion (hence lower speeds) have lower rates than those with less congestion, though their incomes may be similar; Mumbai (BOM) in India with higher congestion has lower rates than Delhi (DEL) in India with lower congestion levels, and New York (NYC) in the USA has a lower rate than Houston (HOU), also in the USA.

Road traffic fatality trends for cities in USA

Figure 5 shows the average annual total fatality rates per 100,000 population for 1,972 cities with population greater than 20,000 persons, and Figure 6 shows that same data for only those cities with population greater than 100,000 persons. These data show the following trends:

- The cities with highest fatality rates can have rates that can be greater by a factor of 3-6 than those with lowest rates.
- The differences between highest rates and lowest rates tend to decrease with increase in city population; however there is a wide scatter at all population levels.

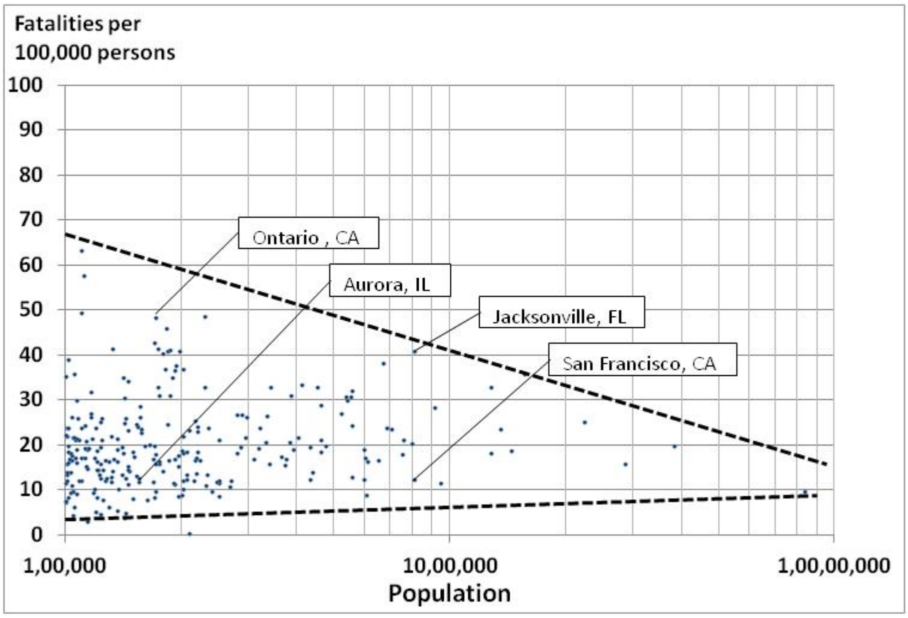

Figure 6 - Average RTI fatality rates per 100,000 persons (years 2004-2008) for 172 cities in USA with population > 100,000 persons.

Figure 6 shows examples of two cities, Jacksonville (FL) and San Francisco (CA), both with populations around ~800,000 but with fatality rates varying by a factor of 4. Two much smaller cities, Aurora (IL) and Ontario (CA) with populations around ~180,000 show similar differences. It is interesting that two cities in the same state of California can have very different fatality rates. Though their income levels, traffic enforcement patterns and traffic rules may be similar.

Table 2 shows 10 cities that have zero pedestrian deaths, of which eight also have no motor vehicle deaths. All these cities have populations between 100 000 and 200 000. This is in contrast with 13 cities in the same population range which have some of the highest rates in the country (Table 3).

For motor vehicle fatality rates to be high, there have to enough crashes where the effective impact velocity is higher than 80-100 km/h for belted and air bag protected occupants. On the other hand, when vehicle occupant fatality rates are, it is possible that average vehicle velocities are low, and therefore there would be less pedestrian fatalities. The same explanation should hold for the 8 cities that have vehicle fatality rates of 0 per 100,000 population (Table 2) which also have rates of zero for pedestrians. The fact that a city can have high fatality rates for vehicles (indicating higher

Table 2 - Ten cities with lowest pedestrian fatality rates in USA.

City	Population	Pedestrian fatality per 100,000 persons	Motor vehicle fatality per 100,000 persons
Ann Arbor, MI	114,024	0	0
Spring Valley NV	117,390	0	0
Elizabeth, NJ	120,568	0	0
East Los Angeles,CA	124,283	0	0
Metairie CDP, LA	146,136	0	0
Sunrise Manor NV	156,120	0	0
Paradise CDP, NV	186,070	0	0
Arlington CDP, VA	189,453	0	0
Bellevue, WA	109,569	0	3.04
Manchester, NH	107,006	0	4.98

average vehicle speeds) and low rates for pedestrians, could imply that these cities would have low pedestrian exposure and hence low rates for them.

Table 3 - Thirteen cities in USA (population < 200,000) with pedestrian fatality rates > 3 per 100,000 population

City	Population	Pedestrian fatality per 100,000 persons	Motor Vehicle fatality per 100,000 persons
Gary, IN	102,746	4.22	15.57
Waterbury, CT	107,271	3.73	12.43
Beaumont, TX	113,866	3.81	14.63
Columbia, SC	116,278	5.16	16.63
Fayetteville, NC	121,015	3.31	7.16
Pomona, CA	149,473	3.12	4.91
Fort Lauderdale, FL	152,397	7.66	12.68
Dayton, OH	166,179	3.41	8.22
Reno, NV	180,480	3.51	4.06
Salt Lake, UT	181,743	3.85	10.09
Jackson, MS	184,256	3.08	17.72
San Bernardino, CA	185,401	3.42	8.99
Orlando, FL	185,951	4.66	13.27

Crash rates and location of crashes by population size

Crashes and number of lanes

Since the population distribution of cities is skewed, we took the natural logarithm of the population and examined the relationship for proportion of crashes occurring on 1-2 lane roads. Figure 7 shows the relationship by city size (populations and proportion of fatal crashes taking place on 1-2 lane roads. The higher the population, the lower the per cent of deaths on 1-2 lane roads as compared to wider roads. However, the plot also shows that there is a wide scatter at each population level.

Figure 8 shows a plot of the per cent of deaths that occur at junctions against city population, and this shows that the higher the population, the higher the per cent of deaths on intersections as compared to midblocks or other types of road junctions. Deaths are more frequent at intersections. Here again, there is a wide scatter at each population level.

Both Figure 7 and 8 show a relationship between location of crashes and city size, but the wide scatter suggests that city size may not actually be the main determining factor in

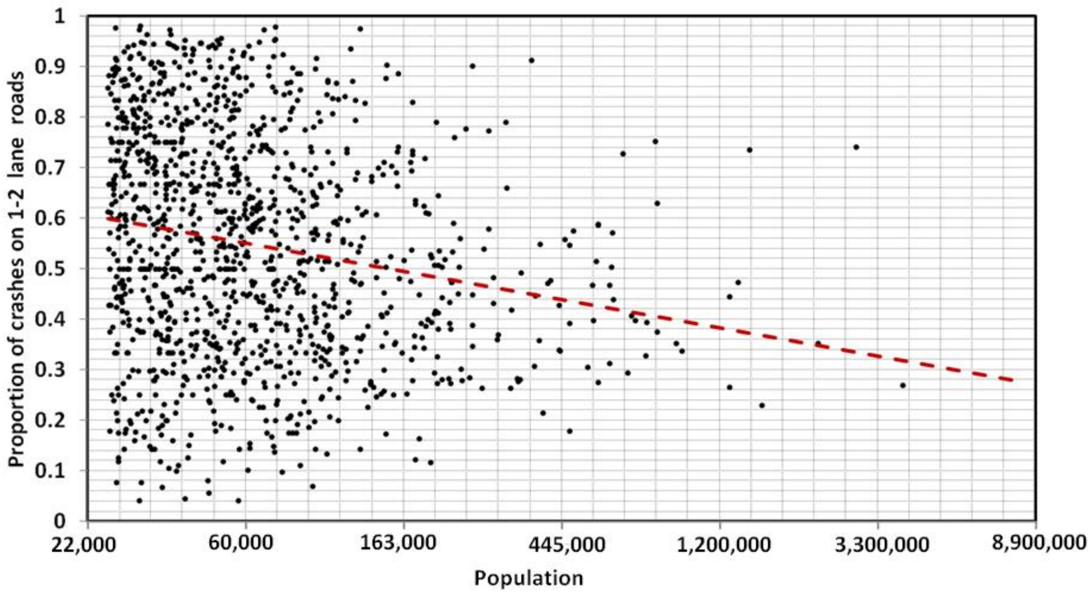

Figure 7 - Relationship by city size (population) and proportion of fatal crashes taking place on 1-2 lane roads

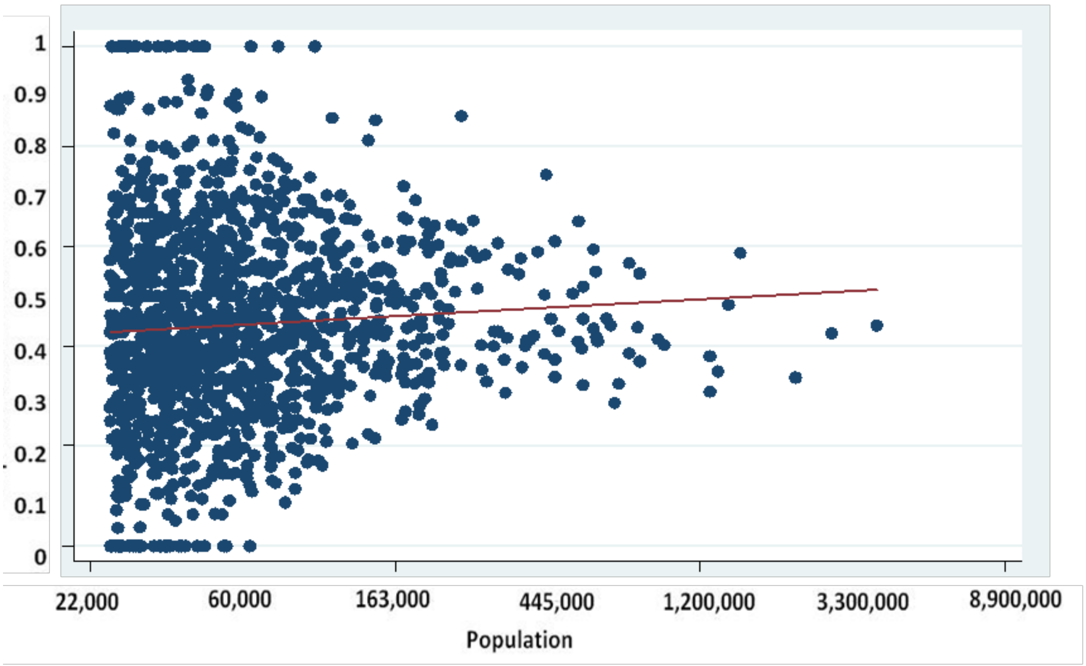

Figure 8 - Relationship by city size (populations and proportion of fatal crashes taking place at junctions

location of crashes.

Since small cities tend to have very few deaths, and all deaths occur ion 1-2 lane roads since they have no wide roads, these were dropped from analysis in regressions. A regression was run to determine the factors that predict the rate of deaths in 1-2 lane roads using population and location by junction/midblock. Limited to 567 cities with population between 25,000-50,000, it showed that the higher the rate at intersection or at midblocks, the higher the rate in 1-2 lane. A pretty decent model as R2~0.75. However when a new variable (binintmid), was generated whether the most common type of junction for deaths is the intersection or a midblock/other, based on the percent of deaths that occur in the different junctions (where binintmid = 1 if the most common junction is intersection versus midblock or other) and ran a logistic regression model to see what factors may predict the probability that deaths occur in intersections versus other types of junctions – we eliminated the extremes.

The result of this is shown in Figure 9. This shows that population size is not a good predictor for location by junction or mid-block. However, when a similar model was run to see whether city size is good predictor for whether more crashes occur on local roads or arterial roads/expressways, we got a better prediction as shown in Figure 10. These results suggest that when rates on principal arterial roads are higher, it tends to be in larger cities.

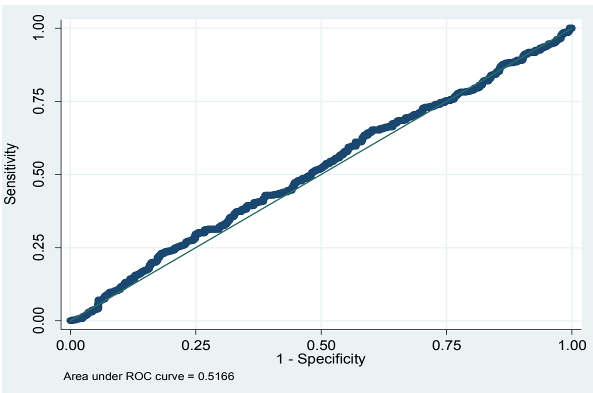

Figure 9 - Goodness of fit model to see whether the most common type of junction for deaths is the intersection or a midblock for ciies of different sizes

While these models give some indication that number of lanes, junction types and type of road are related to fatality rates or where deaths occur, we still need built infrastructure variables to properly model the relationship.

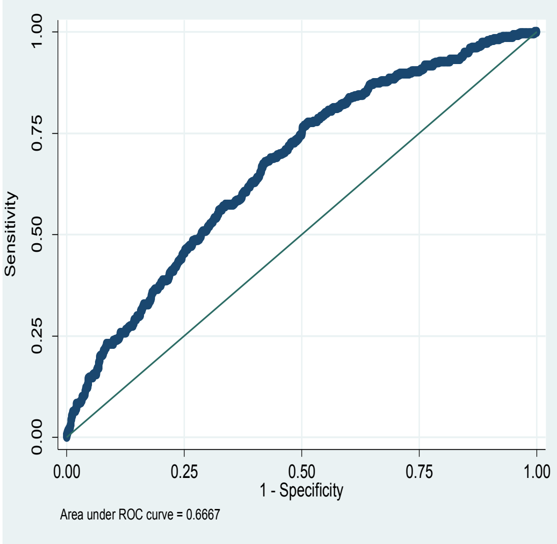

Figure 10 - Goodness of fit model to see whether the most common type of junction for deaths is on local roads or main arterials

Comparison of location of crashes in low and high rate cities in USA

Out of the randomly selected cities shown in Table 1, we used the high and low crash cities for comparison. The very low rate cities with smaller populations had very few crashes and so it was not possible to compare locations of crashes for any statistical analysis. The comparisons of high and lower rate cities show that there is difference in the locations where these crashes occur as shown in Figures 11 and 12. These figures clearly indicate the following:

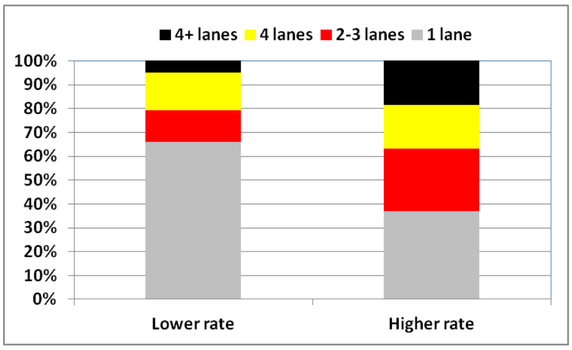

Figure 11 - Location of fatal crashes on different road widths in US cities selected randomly for low and high crash rates

1. Cities with higher crash rates have a higher proportion of crashes on roads that have 4 or more lanes.
2.Cities with higher crash rates seem to have more crashes at mid-block.

Figure 12 - Location of fatal crashes, junction or mid-block, US cities selected randomly for low and high crash rates

We selected two large cities – Chicago with a low fatality rate (16/100,000 persons) and Dallas with a high rate (33/1000,000 persons) to compare these ratios, and the results are sown in Figures 13-15. The data from these two cities confirm that higher fatality rate cities have a greater proportion of crashes on wide roads and at mid-blocks. These results suggest that average speeds could be higher in the high rate cities. Now we have to investigate whether the higher proportion of crashes are due to higher percent of wide roads or other city characteristics that encourage higher speeds by their very form and structure. One possible reason for higher proportion of crashes at midblock could be that the average distance between junctions is higher, allowing motorists to reach higher speeds midblock.

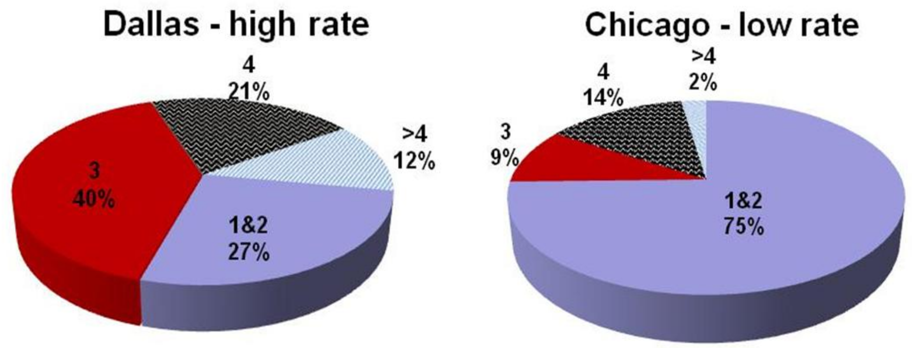

Figure 13 - Proportion of fatalities on roads with different total lanes available in Chicago (low fatality rate) and Dallas (high fatality rate)

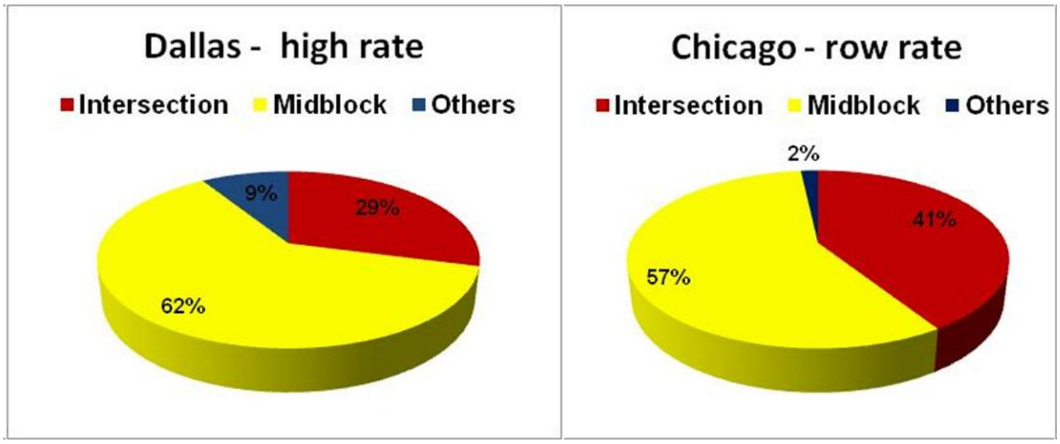

Figure 14 - Proportion of fatalities on roads at junctions and midblocks in Chicago (low fatality rate) and Dallas (high fatality rate)

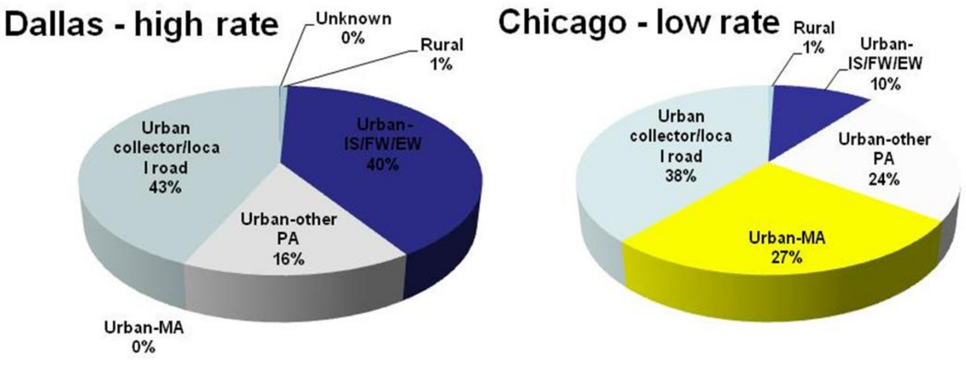

Figure 15 - Proportion of fatalities on roads with different classifications, Chicago (low fatality rate) and Dallas (high fatality rate)

Use of regression models to investigate various aspects of crash location with city size does not seem to give a good understanding of what is really going on. For example, the regression model using all cities (Figure 8) suggests that proportion of crashes on 1-2 lane increases with city size (population). However, the plot shows a great deal of scatter at each city size level. When a few cities are selected randomly for high and low fatality rates and then compared, we find that crash locations do differ between high and low rate cities irrespective of city size (Table 1 along with Figures 11 and 12). Therefore, it is important that we study the differences between high and low fatality rate cities with similar socio economic backgrounds to tease out the influence of urban design on crash rates. Regression models including all cities are not likely to give us the kind of information we need.

The fact that there is a difference in the location of crashes between the high and low fatality rate cities in the US suggest that urban form and street design may be influencing average vehicle speeds in the city. This needs to be investigated further with road and street design details of these cities.

Major differences in fatality rates observed for cities around the world and for those within USA are also observed in India (Figure 16). Interestingly, the distribution for Indian cities is similar to that in the USA – there are greater differences in cities with smaller population than those with large populations. In the absence of more detailed information about Indian cities it is not possible at this time to investigate the factors associated with these differences. It does appear that 'culture' may not be playing a determining role to explain the difference in rates.

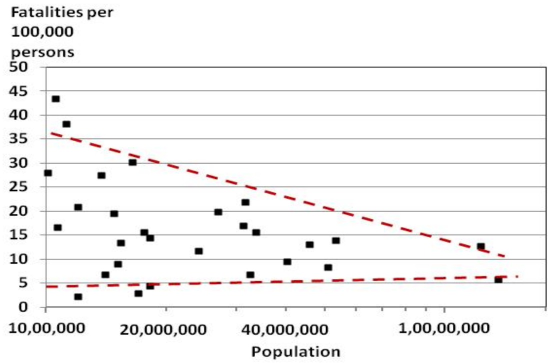

Figure 16 - RTI fatality rates per 100,000 persons for Indian cities with population greater than 1 million persons

Other investigators have used negative binomial regression models to assess the effect of street and street network characteristics on total crashes, severe injury crashes, and fatal crashes (Marshall and Garrick 2011). They used data from over 230,000 crashes taking place over 11 years in 24 California cities at the U.S. Census Block Group level of geography. Their results suggest that denser street networks with higher intersection counts per area are associated with fewer crashes across all severity levels. Conversely, increased street connectivity as well as additional travel lanes along the major streets went along with more crashes. They also report that more lanes resulted in an increase to the expected number of crashes across all severity levels. The average total number of lanes on the citywide streets had one of the higher levels of statistical significance with respect to safety of all the variables in their dataset. A higher percentage of citywide streets with a raised or painted medians was significantly related to increasing overall crash totals and severe injury crashes. However, it is possible that the presence of medians was also associated with the presence of wider streets. Having bike lanes along the citywide streets was associated with a decrease in the expected number of fatal crashes.

Marshall and Garrick's results for a limited number of cities in California reflect what our results for all US cities indicate using a different method. Therefore, it is reasonable to assume that presence of wider roads with long block lengths are associated with higher crash rates in cities. We also know that improvements in crashworthiness of vehicles, use of seatbelts and airbags and other safety devices can reduce fatality rates by 30-70%, alcohol control about 3O%-40% (Peden Margie et al. 2004), and that enhancement in road and infrastructure facilities can lead to an increase in fatalities. But, the differences in rates across cities in US and internationally show a difference by factors of three or more. This seems to suggest that city structure, modal share split, exposure of motorists and pedestrians, may have a greater role in determining fatality rates than vehicle and road design alone.

If it is not easy for city residents to walk, bicycle or use public transport, then they will prefer the use of private modes of transport. When a majority of commuters are dependent on motor vehicle use for their essential needs, the system creates a political demand for greater provision of motor vehicle facilities and road space. This in turn can make it difficult for the political system to be harsh on drivers in terms of speed enforcement and controlling drinking and driving. In this situation, not only do people tend to use motor vehicle for short trips, but also demand facilities that reduce trip time for long trips.

CONCLUSIONS

Most cities around the world are faced with serious problems of inadequate mobility and access, vehicular pollution and road traffic crashes and crime on their streets. Increasing use of cars and motorised two-wheelers add to these problems, and this trend does not seem to be abating in most cities of the world. It is expected that improvements in public transport can help substantially in alleviating some of these problems. However, modern cities, especially in low and middle income countries have very mixed land use patterns, a very large proportion of all trips are walk or bicycle trips; of the motorised trips, more than 50% are by public transport or shared para-transit modes (Mohan, 2008). Deaths and injuries due to road traffic crashes are also a serious problem in these cities.

Walking and bicycling are the only clean modes of transport available. The use of these modes tends to reduce as incomes rise and cities become unfriendly to these modes when they design roads with only motor vehicles as a priority. The high risk of injuries and fatalities in urban areas to pedestrians, bicyclists and commuters in access trips have been documented from all over the world. Unless walking, bicycling and access to public transport is made safer, it will be difficult to promote these modes.

The data presented in this study show that:

1. Fatality rates in cities are not solely determined by income levels or city size. RTI fatality rates among cities with similar incomes or similar population levels can vary by a factor of 3-5. This indicates that city street structure and urban form can have a very significant effect on RTI fatality rates over and above issues of vehicle design and enforcement.
2. It may be more useful to compare cities with very different RTI fatality rates rather than taking all cities in the sample to tease out the real factors influencing road safety.
3. Cities with a higher proportion of wide streets and low density road networks appear to have a much higher RTI fatality rate.
4. Urban form and street design patterns may have to be given much more importance to improve safety of pedestrians, bicyclists and transit users.

This suggests that we must spend more time in understanding the role of urban design and its influence on traffic safety as the present knowledge is inadequate. Once we are able to design safer cities, we can then promote cleaner modes of travel more easily. Therefore, urban safety becomes a necessary condition for control of global warming.

ACKNOWLEDGEMENT

This work was partially funded by the Volvo Research and Educational Foundations.
Aishwarya V. Chaturvedi assisted in data collection and analysis.

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APPENDIX 1

Three letter airport codes for cities included in Figure 4.

CODE	CITY	CODE	CITY
ACC	Accra	IXC	Chandigarh
ADD	Addis Ababa	JNB	Johannesburg
ADL	Adelaide	KIX	Osaka
AMD	Ahmedabad	KUL	Kuala Lumpur
BER	Berlin	LAX	Los Angeles
BKK	Bangkok	LON	London
BNE	Brisbane	MAA	Chennai
BOG	Bogota	MEL	Melbourne
BOM	Mumbai	MEX	Mexico City
BOS	Boston	MNL	Manila
BRU	Brussels	MPM	Maputo
CCU	Kolkata	MUC	Munich
CGK	Jakarta	NBO	Nairobi
CGP	Chittagong	NYC	New York City
CHI	Chicago	PAR	Paris
CLO	Cali	PEK	Beijing
CPT	Cape Town	PHX	Phoenix
DAC	Dhaka	PLZ	Port Elizabeth
DEL	Delhi	PNQ	Pune
DEN	Denver	PRY	Pretoria
DKR	Dakar	RUH	Riyadh
DTT	Detroit	SEL	Seoul
DUR	Durban	SIN	Singapore
DXB	Dubai	TPE	Taipei
GRU	Sao Paulo	TYO	Tokyo
HIW	Honolulu	VIE	Vienna
HKG	Hong Kong	WAS	Washington
HOU	Houston		