WHAT MAKES CITIES SAFER BY DESIGN? A REVIEW OF EVIDENCE AND RESEARCH ON PRACTICES TO IMPROVE TRAFFIC SAFETY THROUGH URBAN AND STREET DESIGN

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Word count summary:
Abstract: 241
Text: 3,485
Table & Figures: 1 Figure (250 words) = 250
References: 1,639
Total word count: 5,615
Submission Date: August 1, 2015
ABSTRACT

Traffic fatalities kill over 1.24 million people globally each year, and are expected to rise to the 5th leading cause of death in the world by 2030. The way cities are laid out in terms of their land uses and street grids, as well as how streets are designed can have great impact on traffic fatalities and injuries. Yet there are few resources that holistically review both urban and street design in fostering traffic safety for all road users. For this reason, this paper provides a compendium of the evidence on different urban and street design elements that embrace practices to (a) reduce exposure by preventing the need for vehicle travel, thus preventing a crash before a trip would even begin; and (b) diminish risk by encouraging safer vehicle speeds and prioritizing pedestrian and bicyclist safety. Measures were found in the following six categories to achieve this: 1) connected and compact urban design; 2) traffic calming measures to slow traffic to safe speeds for pedestrians; 3) managing safety on urban arterials, especially at intersections and in protecting vulnerable users; 4) prioritizing pedestrian facilities; 5) providing a connected network of safer bicycling infrastructure; and 6) creating safe access to high-quality public transport. This paper provides a basic review of evidence useful for safe system approaches to traffic safety, such as Vision Zero. More advanced meta-analyses and research in cities around the globe is needed to further inform effective urban and street design.
1 INTRODUCTION
Traffic fatalities kill over 1.24 million people globally each year, and are expected to rise
to the 5th leading cause of death in the world by 2030 (1). Furthermore, road crashes are
the leading cause of death among young people ages 15–29, and the second leading cause
of death worldwide among young people ages 5–14 (2). People from lower
socioeconomic backgrounds are more likely to be involved in traffic crashes, and often
live in areas with low-quality infrastructure (3). Older pedestrians and cyclists can
account for up to 45 percent of pedestrian fatalities and up to 70 percent of cyclist
fatalities (4).

The way cities are laid out in terms of their land uses and street grids, as well as
how the streets themselves are designed can have a great impact on how many traffic
fatalities and serious injuries occur. For this reason, this paper provides a compendium of
the evidence that exists on different urban and street design elements that can enhance
traffic safety. The research shows that promoting sustainable urban development,
together with sound street design, can have a strong and positive relationship with traffic
safety. This information is useful to help cities taking safe system approaches to traffic
safety, such as Vision Zero, that place responsibility for traffic safety in the hands of road
designers.

2 METHODOLOGY
The safest cities in the world in terms of traffic safety include Stockholm, Berlin, Hong
Kong, and Tokyo with traffic fatality rates near 1 to 1.5 per 100,000 residents, as opposed
to places such as Atlanta with around 10 fatalities per 100,000 residents (5).

These cities and others with lower levels of traffic deaths share certain
characteristics. Research shows that there are fewer fatalities in places with fewer vehicle
miles traveled, and that lower vehicles speeds, preferably at 30 km/h (18.5 m/h) and no
more than 50 km/h (35 m/h) will result in fewer pedestrian fatalities (6, 7). This means
that safer cities tend to embrace practices that (a) reduce exposure, via preventing the
need for vehicle travel, thus preventing a crash before a trip would even begin; and (b)
diminish risk via safer vehicle speeds and properly addressing this where mixed land
uses and vulnerable road users are present.

What more specific approaches can cities take to achieve this? What are the urban
and street design elements that reduce exposure and diminish risk? There are not
currently any well-known collections of research that bring together these two issues of
urban design and street design.

In order to obtain a better understanding of these relationships, the authors
gathered evidence available on the built environment and street design related to traffic
safety. Based on the studies available, the topics were organized into six key categories
which cities can consider for improving traffic safety through urban and street design: 1)
connected and compact urban design; 2) traffic calming measures to slow traffic to safe
speeds for vulnerable road users; 3) managing safety on urban arterials and main roads,
especially at intersections and in protecting vulnerable users from mistakes of drivers; 4)
prioritizing pedestrian facilities; 5) providing a connected network of safer bicycling
infrastructure; and 6) creating safe access to high-quality public transport. This paper
provides a basic understanding, but more advanced meta-analyses and research in cities
around the globe are needed to further inform effective urban and street design.
3 RESULTS

A summary of this research and descriptions of each element to pursue safer urban and street design is provided.

3.1 Compact and Connected Urban Design

Cities can be safer when they have more compact and connected urban form that reduces the need for driving and fosters shorter trips. In a study from the United States, urban sprawl—places with less density, long blocks, and a lack of street connectivity—has been “directly related to traffic fatalities and pedestrian fatalities” (8). For every 1 percent change toward a more compact and connected urban form, all-mode traffic fatality rates fell by 1.49 percent and pedestrian fatality rates fell by 1.47 to 3.56 percent. In fact, densely populated New York City had the least fatalities in the United States, while the most sprawling areas of Atlanta and elsewhere the highest. Other research shows that this is because people drive less in the compact, mixed-use areas and that connected urban form tends to lower vehicle speeds (9).

Research shows smaller block sizes help slow traffic and make walking easier. Dumbaugh and Rae (10) found that while smaller blocks can lead to more traffic crashes (excluding the effects of other street designs), they lead to fewer fatal crashes and injuries due to lower speeds. Evidence from China has shown that the long block faces (superblocks) encourage midblock crossing on arterials, putting pedestrians at a high risk (11). In Guadalajara, Mexico, the total length of all approaches to intersections and the number of injurious and fatal crashes at intersections were found to be significantly related (12).

Superblocks often are abutted by wide arterial roads that make pedestrian crossing less safe. Evidence from Mexico City shows that as the maximum pedestrian crossing distance at an intersection increases by 1 meter (3.3 feet), the frequency of pedestrian crashes increases by up to 3 percent (13). Each additional lane also increases crashes at all severity levels (13). The most significant relationship to injury crashes was found to be street width and street curvature, with one study showing the safest residential street width of 7.5 meters (24.5 feet) (14).

Providing a connected street network and nearby access to destinations can reduce the need for driving and thereby reduce overall exposure of road users to traffic fatalities. For example, a meta-analysis shows that street connectivity is one of the most important factors in fostering walking and reducing vehicle travel, with less vehicle travel strongly linked to destination accessibility (15).

Lastly, though not directly related to traffic safety, when coupled with the above, population density may help cities create less car-dependent residents, and improved overall safety. Dumbaugh and Rae (10) found that for an increase in density of 100 persons / square mile, there was a 6 percent reduction in injurious crashes and a 5 percent reduction in all crashes, after controlling for VMT, street connectivity, and land use. This is supported by a meta-analysis from 10 separate studies showing population/household density linked to increased walking and mass transport use and reduced vehicle travel (15).
3.2 Speed Management Measures

Lower automobile speeds, especially those below 30 kilometers per hour (18.5 m/h), have been found to drastically lessen the risk of fatalities (7, 16, 17, 18, see FIGURE 1).

A number of traffic calming measures can help bring vehicle speeds to safer levels through street design (19). These include speed humps and cushions, chicanes, chokers, curb extensions, traffic circles and roundabouts.

Speed humps, or artificial elevations in the road can slow traffic. Studies from Norway show that humps reduce the number of injury crashes by around 50 percent, and that on average, newly installed humps reduced mean vehicle speeds from 36.4 to 24.4 km/hr (22.6 m/r to 15.2 m/r) (20). A variation, speed cushions, which allow wide axle vehicles to pass over have been shown to also reduce vehicle speeds but allow buses and emergency vehicles to pass without hitting the bump.

Chicanes are curves in the road to slow cars, and available data for chicane schemes have indicated a reduction in injury crashes (54 percent) and crash severity (21).

Measures that narrow down curbside width of a street can reduce vehicle speeds and therefore make streets safer. Curb extensions are simple interventions to extend curbs into parking lanes at intersections or at mid-block that reduce crossing distance. Chokers, which narrow a street temporarily through extending curbs or other fixed materials, have typically reduced speeds on average by 4 percent for two-lane chokers and 14 percent for one-lane chokers (22).

Raised pedestrian crossings that keep the pedestrian pavement at a level grade as it passes over streets has shown to reduce the speed of vehicles by 10 percent, as cars are forced to slow down when turning (22).

Lastly, neighborhood traffic circles and roundabouts have shown to improve traffic safety. A study of 119 residential traffic circles installed in the city of Seattle between 1991 and 1994 found that reported crashes in those areas declined from 187...
before installation to 11 after installation, and injuries declined from 153 to 1 in the same period (23). Well-designed and placed roundabouts reduce the number of injury crashes by 10 to 40 percent, depending on the number of legs and the previous form of traffic control, though this should not be considered for high vehicle and pedestrian volume areas. A reduction of 70–90 percent has been found for fatal and serious injury crashes (20).

3.3 Managing Arterials

Ensuring safety for all road users is especially true with arterial corridors. A nationwide study from the U.S. shows that more than 50 percent of all pedestrian fatalities occurred on arterial roads in urban areas compared to 14 percent on local roads or streets (24). Pedestrian-scaled retail configurations have been associated with fewer fatal crashes as opposed to layouts of big box stores with large parking lots along busy urban arterials (10). Research from Mexico has shown that most crashes are likely to occur on wide arterials; similar findings are shown in New York City and elsewhere (25, 26).

Designers need not provide wide lanes on arterials. A study of urban streets in Tokyo and Toronto found that both narrow (less than 2.8m) and wider (over 3.2–3.4m) vehicle lane widths have proven to increase crash risks with equal magnitude (27).

Pedestrian crossings ought to receive special attention. One before-after study of intersection improvements in Beijing found that crosswalk striping—along with bus stop redesign, pedestrian barrier construction, increased illumination, and new signals—increased both real and perceived pedestrian safety (28). Medians and median refuge islands also help crossings. Evidence from crash frequency models in Latin American cities suggests that medians can reduce crashes, including severe crashes, by 30–40 percent (13). Refuge islands have been shown to decrease the percentage of pedestrian crashes and casualties by 57–82 percent in the US (29). In addition, measures such as Lead Pedestrian Intervals to give pedestrians a brief head start have been found to reduce the odds of pedestrian conflict with turning vehicles were reduced by 95 percent in the beginning walk period (30).

In some cities, motorcyclist deaths are a significant problem, but there is not a clear indication of what infrastructure will work. Exclusive motorcycle lanes on trunk roads in cities in Malaysia has been found to reduce motorcycle crashes. (31, 32, 33). Yet in São Paulo, the results of exclusive lanes have been described as mediocre, though the city did see a reduction in crashes when it banned motorcycles on the central lanes of a main expressway (34). A study from Malaysia found that an increase in the speed at which motorcycles approach signalized intersections is associated with more motorcycle crashes, and that more motorcycle crashes occur at signalized intersections located within commercial areas (35). So reducing speeds overall through the appropriate types of speed management measures may be one positive approach to motorcycle issues.

3.4 Prioritizing Pedestrian Space

WHO reports show that each year, more than 270,000 pedestrians lose their lives on the world’s roads (3). Pedestrians are most at risk in urban areas due in part to the large amount of pedestrians and vehicle activities occurring and concentrated in cities (36). This is especially the case in developing countries, where many cities’ sidewalks are poorly maintained or not maintained at all. In India, statistics show that the pedestrian
fatality share is over 40 percent in metropolitan areas like New Delhi, Bangalore, and Kolkata (37). A variety of measures, from providing basic sidewalks to pedestrian streets, shared streets, school zone treatments, and street plazas can help improve safety. Evidence from the U.S. shows that pedestrian crashes are more than twice as likely to occur in places without sidewalks; streets with sidewalks on both sides have the fewest crashes, showing how simply basic facilities can have great benefit (38).

Other more advanced measures can further improve safety in certain settings. Results of crash investigations in the Netherlands indicate that converting streets to “woonerfs” (streets shared by all users but designed to prioritize pedestrians and limit vehicle speeds) leads to a reduction of approximately 50 percent in the number of crashes on them (39, 40). Evidence from shared streets in Seven Dials, London shows that—based on two years of “before and after” monitoring—casualties fell from 71 in the period before the street was remodeled to 40 afterwards—a drop of 43 percent (41).

New York City has shown a decrease of 16 percent in speeding and a 26 percent reduction in injury crashes along streets that contain pedestrian plazas, which are new public spaces that take away underused street space and help reduce crossing distances (42). In Seoul, South Korea, crashes decreased by 39 percent in school zones after traffic calming and improved pedestrian pavements were put in place (43).

Closing streets to cars has also been shown effective. Survey results from Bogota, Colombia show that open streets (street closures on weekends) participants report feeling safer on open streets (44). Complete pedestrianization can reduce crashes by 50 percent or more, though buffer areas may see an increase in crashes, unless extra measures are taken (20). Evidence from Istanbul also shows pedestrianization increased retail sales, resident perception of traffic safety, air quality, and walking rates (45).

3.5 Creating a Network of Safer Bicycling Infrastructure
Bicyclists require special attention in street design, as they are one of the most vulnerable users in traffic to fatalities and injuries, yet an increase in safety and usage can lead to greater health and environmental benefits. Cities such as Copenhagen, New York City, and Minneapolis have witnessed significant decreases in the bicyclist fatality and injury rates after building networks of safer bike infrastructure (6). A recent account from Bogota, Colombia found that adding more than 100 km (62 miles) of bikeways helped reduce bicyclist deaths by 47.2 percent between 2003 and 2013, and doubled bicycle use from just over 3 percent of all daily trips to over 6 percent (46).

Bicycle lanes need to be designed correctly to improve safety risks. Cycle lanes in general have been found to only show a mean estimate of 4 percent reduction of injury crashes (20). Though when removing a lane of traffic and providing physical protection, impacts may be greater. A new cycle track in New York City has reduced speeding rates from 74 percent to 20 percent. Crashes and injuries of all kinds dropped by 63 percent (47).

When it comes to bicycle paths, clearly marked, bike-specific paths have shown to provide improved safety for cyclists compared to mixed-user bike paths (48). Studies have shown that collisions between cyclists and pedestrians result in significant injuries, and that increased controls of shared spaces may reduce the burden on pedestrian injury, particularly older pedestrians (49). Off-street bike paths were found to be one of the safest bicycle routes in Vancouver, Canada (50). And shared bicycle streets (with low
speed traffic and special diverters for cars) have shown positive results. Evidence from Berkley, CA shows that collision rates on “bicycle boulevards”, a type of shared bicycle street, are two to eight times lower than those on parallel, adjacent arterial routes (51).

Special care is also needed in designing intersections, where motor vehicles and bicycles can conflict. In Portland, Oregon, seventy-seven percent of cyclists felt bicycling through the intersections was safer with bike boxes (areas ahead of stop line for bicyclists to queue), and bike boxes reduce motor vehicle encroachment at intersections by almost 20 percent (52). Improving intersection design to provide two-step left turns resulted in a reduction in safety conflicts between motor vehicles and bicyclists by 24 percent in Beijing (28). A study from Finland and another from the Netherlands found that speed-reducing countermeasures (e.g. raised bicycle crossings) improved drivers' visual search patterns in favor of the cyclists coming from the right, giving more time to notice cyclists (53, 54). Lastly, dedicated bicycle signals may help, with evidence from Portland showing that bicycle signals can reduce the number of bicycle/vehicle collisions (55).

3.6 Safety on Transit Corridors and Access to Transit

Well-designed public transport is a key component of safer city streets. High-quality mass transit provides the safest form of mobility possible, moving more people in a safer way than other modes (56, 20). In many cities, especially in low and middle-income countries, however, informal mass transit with little oversight (57) is perceived to be unsafe and generally associated with an increased risk of crashes. The main safety risks on transit corridors depend on its geometric design rather than the type of technology used (bus or rail) or the region of the world it is in (13). Crash frequency models suggest that each additional lane entering an intersection increases crashes by 10 percent, and that simpler intersections on transit corridors are safer (13). Evidence from Bogota, Mexico City, and Guadalajara show that allowing mixed traffic to enter a bus lane is a safety risk and results in increased collisions with buses (13). Each added left turn movement at an intersection may increase pedestrian crashes by 30 percent and vehicle collisions by 40 percent (from EMBARQ models for Mexico City and Porto Alegre). Median busways have shown both a higher impact on safety as well as better operational performance (13). 93 percent of pedestrian crashes in Porto Alegre occurred at midblock locations as opposed to intersections (calculated from 2011 crash data).

In addition, data shows that people are considerably safer when they are in the bus or on the station platform than when they are walking to and from the bus station, and that same-platform transfers are the safest for bus systems (13). Studies also show that major transfer stations are the locations with the highest number of crashes on many public transport systems, due to the large volumes of traffic and increased exposure for pedestrians (13).

In terms of trams or streetcars, these running at-grade within mixed traffic have been identified as the least desirable design due to potential conflicts with other modes of transit, which can impede traffic, limit transit speed and reliability, and pose safety risks to both vehicles and pedestrians (58). Conflicts also can be found at intersections, especially where turning vehicles may be crossing the path of the tram. This requires separate signals for turning vehicles, though banning left turns would go further in reducing the chance of a tram hitting a turning vehicle (59).
A study from Sweden showed that three-quarters of those injured in bus and tram incidents sustained their injuries at bus or tram stops, or at pedestrian crossings (60). Measures to improve safety include reducing vehicle speeds through speed humps, raised pedestrian crossings, or other traffic calming measures, shortening crossing distances, and ensuring clear visibility at station entries and exits. Horns or bells can alert pedestrians of a coming train. Among other interventions, arms can close off the track area to prevent pedestrians from crossing when trains are passing (61).

4 CONCLUSION
This paper provides a comprehensive literature review on street and urban design measures that are shown to have the potential to increase traffic safety. Taken together, these key considerations can reduce vehicle travel while lessening the risk of injury for everyone, especially pedestrians and cyclists. More research is needed, particularly in low- and middle-income countries on the impact of such measures, and how they can be applied in a different local contexts.

Policies are beginning to embody this framework for a safer city. Mexico City’s Mobility Law and policies recommended by the European Traffic Safety Council are providing a hierarchy of modal priority that begins with pedestrians, followed by cyclists, mass transit, and lastly, private vehicles, to address concerns such as safety and sustainability ahead of moving only motorized traffic (62).

This is especially important given the large numbers of pedestrians and bicyclists on the road and the large proportions of victims of traffic accidents from the vulnerable road user group. In most Latin American cities, walking alone comprises around 30 percent of all trips (63). Chinese and Indian cities also have high rates of walking, bicycling, and motorcycling, yet the street conditions can be hazardous to these road users: 70 percent of traffic deaths were among these groups in China, while 46 percent of traffic deaths were in India (1). Infrastructure improvement is much needed to reduce traffic accidents and its social costs. By getting urban and street design right, cities can become not only safer, but places that can benefit health, economic development, and quality of life.

REFERENCES


