URBAN STREETSCAPE DESIGN AND CRASH SEVERITY

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ABSTRACT

Streetscape design is increasingly acknowledged as a tool for improving traffic safety and livability in urban settings. While traditional highway safety engineering promotes widening and removing obstacles from roadside “clear zones” to reduce collision potential, a contrasting framework proposes that smaller, more enclosed streetscapes may incentivize slower, less risky driving and therefore improve both livability and safety outcomes. Such a strategy may have particular relevance along urban arterials, where large clear zones may be impractical due to complex adjacent land uses and promotion of livable spaces is an increasing focus.

This study examined streetscape design and traffic safety in urban settings by assessing relationships between crash severity and streetscape design variables in New York City. A GIS-based method was used to precisely capture streetscape design measurements at the locations of more than 240,000 crashes. Logistic regression models indicated that crashes on smaller, more enclosed streetscapes were less likely to result in injury or death compared with those on larger, more open streetscapes. These results point to infill development and street tree planting as safety countermeasures that are consistent with additional livability goals such as walkability, high quality public realm design, and provision of natural amenities.

Key Words: streetscape design, traffic safety, urban arterials, livable streets, GIS
INTRODUCTION

A growing body of research agrees that the built environment design of urban streetscapes has an important and traditionally misunderstood effect on traffic safety. Highway engineering in rural environments traditionally stresses the importance of clear zones on either side of a roadway to provide long sight lines and leeway for driver error and recovery (1). In contrast, recent studies in urban settings suggest that “human scale” streetscapes, which are smaller and more narrowly enclosed by buildings and trees, may reduce crash risk by narrowing drivers’ fields of view and encouraging slower, less risky driving behavior (2–11). Enclosure is the collective effect of large objects surrounding a street, chiefly buildings and trees, to define the spatial extents of a streetscape and restrict long sight lines; it is what some urban designers say makes a street feel like an “outdoor room” (12) (Figure 1). Small and enclosed streetscapes are also consistent with a host of livability goals, including increased land use density, walkability, and urban forestry (13, 14). Traffic safety benefits offer yet another rationale for more densely developed streetscapes, especially along urban arterials where high level of service for vehicular traffic must be accommodated alongside complex land uses and design of vital public spaces.

FIGURE 1 Examples of Open Versus Enclosed Streetscapes.

To objectively investigate the effects of streetscape design on livability performance measures such as traffic safety we use a GIS-based method for block-by-block measurement of fundamental design characteristics—e.g. width, height, continuity of edges—forming a streetscape skeleton that is elemental to user perceptions of spatial scale and enclosure. The GIS-based approach offers greater collection efficiency and measurement consistency compared with manual auditing methods traditionally used to measure streetscape design (13, 15, 16). It also offers more direct and spatially discrete measurements than built environment design proxies based on from zoning, land use districts, or roadway characteristics such as the number travel lanes (7, 17). Measurement of streetscapes at the resolution of individual blocks is particularly important in urban settings, where there can be substantial design heterogeneity within neighborhoods or along corridors. Spatially aggregate built environment measurements may not adequately reveal the implications of design anomalies, such as vacant lots, along individual
LITERATURE REVIEW

The traditional framework associating roadside design with traffic safety is rooted in rural and suburban settings with ample space to either side of roadways and limited diversity of users. It encourages consistently large shoulders and clear zones to allow ample space for recovery from potential driver error or reaction to unforeseen circumstances, such as an animal darting into the roadway (1) (Figure 2, A). More open space along roadsides provides an opportunity for drivers to regain control of a wayward vehicle before crashing into a fixed object.

Unfortunately, such designs can also encourage higher speeds and riskier driving behavior, negatively affecting traffic safety. This is particularly problematic along urban arterials, which attempt to accommodate both heavy vehicular traffic and non-vehicular users who are vulnerable to high-speed crashes. Urban arterials also have limited space for roadside clear zones due to dense land uses and multimodal infrastructure such as sidewalks and bicycle lanes. Traffic safety along urban arterials is, therefore, largely dependent on encouraging drivers to maintain moderate speeds and avoid risky behavior. Rather than assume dense and complex urban roadside environments are a hindrance to traffic safety, as the traditional framework suggests, it is pertinent to investigate how enclosed streetscapes, which are often inherent to urban settings, may instead improve safety by encouraging responsible driver behavior.

An alternative framework relating roadside design to traffic safety, potentially better suited to urban settings, posits that drivers are more aware of potential hazards and engage in less risky behavior when their environment is more constrained and offers less design consistency (Figure 2, B) (3–7). It takes advantage of driver agency to respond to environmental conditions with slower speeds, improving capacity to react to unpredictable events and reducing the severity of crashes when they do take place. This framework may be particularly appropriate for urban settings where complex traffic patterns and diversity of road users make speed a dominating factor in crash severity (18–22).

More enclosed built environment designs with minimal building setbacks, smaller spaces between buildings, and substantial street tree canopy, are also consistent with livability goals promoting walkability, vibrant public spaces, and urban forestry (13). Determining how smaller and more enclosed streetscapes are beneficial to traffic safety may eliminate the perceived tradeoff between clear zones for traffic safety prioritization and “human scale” streetscapes for livability. By using compact streetscape design to encourage responsible driving behavior it may...
be possible for heavy vehicular traffic flows, bicyclists, pedestrians, and dense land uses to more safely share arterial corridors as livable urban spaces.

(A) Driver Error Motivated Framework (Traditional)

![Diagram showing the relationship between driver error and larger, more open streetscape.]

(B) Built Environment Motivated Framework

![Diagram showing the relationship between smaller, more enclosed streetscape and less risky driver behavior.]

**FIGURE 2** Contrasting Frameworks for Safety Design.

Existing research has demonstrated the safety benefits of smaller, more enclosed streetscapes in a generalized sense, but has inadequately investigated the effect of specific streetscape design characteristics. Such studies have drawn on land use and roadway data as indicators of built environment design rather than direct measurements of the streetscape. Several papers by Dumbaugh have evaluated built environment-safety relationships using parcel-level land use data aggregated by census units (3, 5, 8, 11, 22). He and his coauthors consistently found that streets lined by parcels with strip malls and big box stores were associated with greater crash risk, while those lined by “pedestrian-scale” retail were less risky. The Dumbaugh method assumes consistent site and architectural design among land uses, and does not capture differences in building setback, spacing and height that have important effects on streetscape enclosure. Other studies have used the number of traffic lanes or roadway width as an indicator of streetscape size, though this captures little to nothing about the built environment surrounding the roadway (4, 19). Neither of these methods sufficiently accounts for the role of street trees, which provide important roof-life enclosure for many streetscapes. Increasing availability of high resolution building and tree canopy GIS data in urban centers makes it more realistic to include block-level streetscape design measurement in livability analyses.

Many studies have also evaluated relationships between urban form—largely discussed in terms of street patterns and development density—and traffic safety, assuming that gridiron street networks with smaller blocks and higher population density indicated smaller, more enclosed streetscapes (3–5, 8, 10, 11, 22–25). These variables were consistently associated with reduced crash risk, but potentially due to their effect on traffic flow and travel demand more than streetscape design. Urban form logically impacts safety outcomes by affecting mode share—denser, more connected land uses require fewer vehicle trips (21)—and distribution of traffic throughout the network. Sprawling land use patterns can feed traffic into a hierarchical structure,
redistributing crashes away from local streets and toward collector and arterial streets that are also more likely to include car-focused retail and commercial land uses (11). Thus, there is greater propensity for crashes where higher speed vehicular traffic, pedestrian flows and commercial activity are concentrated. These conditions likely have a major effect on livability, but are not necessarily the result of deliberate streetscape design.

As with all traffic safety research, those evaluating the effect of built environment design have struggled to properly account for risk exposure. Standardizing crash rates by vehicle miles traveled (VMT) has been the most common strategy to account for exposure; several studies have used it as the sole exposure metric for all types of crashes, including those involving pedestrians (3, 5–8, 24). Other researchers have constructed pedestrian exposure metrics using land use proxies. Ukkusuri et al. (4) used population and the number of intersections as proxies for pedestrian exposure. Ewing et al. (10) measured pedestrian exposure as the proportion of work trips made by walking and public transit. Wang and Kockelman (25) used modeled pedestrian traffic volume based on a host of land use variables. Each of these provided indirect measures of exposure within areal units, making them particularly inadequate for disaggregate analysis of crashes at specific locations. None accounted for nonlinearity between safety performance and traffic volume by adjusting exposure according to validated safety performance functions (26). Following Hanson et al. (19) and Moudon et al. (20), this study avoids the necessity of exposure control by modeling the effect of streetscape design on the severity of crashes rather than their occurrence. It investigates how specific streetscape design characteristics may be treated as countermeasures to improve livability by reducing crash severity.

METHODS

Study Area

New York City was an opportune study area for examining relationships between urban streetscape design and crash severity because it offered a large sample of traffic crashes reported with a consistent format and occurring in highly variable streetscape environments. With a population of over eight million, more than 45,000 kilometers of public roadways (approximately 8% classified as arterials), and an estimated 108 million kilometers of vehicle travel in 2014, there are more than 100,000 crashes each year on New York City roadways (27, 28). The sheer number of crashes reported by the New York Police Department (NYPD) provided a sample size and consistency that would have been difficult to achieve in other U.S. cities. Moreover, the City of New York provided public access to high quality built environment data, including building footprints, building heights, and tree canopy coverage, that allowed us to precisely measure streetscape design at the location of each crash.

Data

All crash and streetscape design data used for this study were available from the New York City OpenData web portal (27). The study assessed 244,684 NYPD-reported crash records dating from August, 2011 through September, 2013. As demonstrated by Figure 3, crash sites were distributed throughout the city. Each crash record included geographic coordinates and the number of resulting injuries or deaths among drivers, passengers, bicyclists, and pedestrians. Information about the types of vehicles involved, causes, and other factors were inconsistently
coded, so they were not used for analysis. Severity was calculated for each record based on whether the crash resulted in an injury death: those with no injuries or deaths (73% of records) were coded as 0 and labeled *property damage*; those resulting in at least one injury or death (27% of records) were coded as 1 and labeled *injury or death*. This coding potentially oversimplified the relationship between injury and death, but provided reasonably balanced categories for analysis. Less than 1% of crashes in the sample resulted death. Among *injury or death* crashes, 40% included the injury or death of at least one driver, 34% of at least one passenger, 34% of at least one pedestrian, and 12% of at least one bicyclist. The dataset unquestionably underrepresents pedestrian involvement because it counts them only if they were injured or killed; no *property damage* crashes involved pedestrians. The dataset only reported crashes involving at least one motor vehicle. Bicycle-pedestrian or bicycle-bicycle crashes were not included in the database.

**FIGURE 3** Crash Sites Distributed Throughout New York City.

Crash records were linked to streetscape design variables measured along street segments at the approximate location of each crash. Because approximately 96% of crashes occurred at intersections of two or more streets, variables were averaged among all segments within twenty
meters of each crash location. The twenty-meter radius was large enough to aggregate
measurements from streetscapes on opposite sides of large intersections while being small
enough to avoid inappropriate aggregation of adjacent, parallel blocks. While it would have
improved analytical precision to account for streetscape design only for segments along which
participants in each crash were traveling, pre-crash trajectories were not included in the crash
data. Moreover, because the scale and proportions of intersections were influenced by all
streetscapes leading into them, we considered it important to account for all potentially
influential streetscapes.

A GIS-based streetscape measurement method was used to measure each of the 73,764
street segments within twenty meters of the crash sites (29). Input GIS data for the method
included street centerline, building footprint and height, and tree canopy layers, all acquired from
the NYC OpenData web portal. The street centerline dataset represented approximate roadway
centerlines. Building footprint geometry and heights were originally derived from
orthophotography and stereoscopic height measurement. Tree canopy areas were originally
derived by the University of Vermont Spatial Analysis Lab using orthophotography and aerial
LiDAR data to precisely detect tree crowns in urban settings at one square meter resolution.
Intersections were defined where multiple centerlines intersected at a single point. Street
segments representing city blocks, the units of analysis, were defined as the centerline distance
between adjacent intersections. Segments less than twenty meters long, which largely
represented turning lanes within large intersections, were excluded from analysis, as were alleys,
ramps, bridges, tunnels, and expressways.

To “search” for streetscape edges the method drew progressively larger buffers at one-
meter intervals from each side of each block-length centerline and evaluated the proportion of
each buffer overlapping with building footprints. A streetscape edge, where façades consistently
aligned, was identified at the buffer distance where the proportion of building overlap most
rapidly increased relative to the previous buffer. The method searched for façade alignment
within forty meters of each side of each centerline. Segments with no buildings within forty
meters were assumed to have no well-defined street wall. We considered this a reasonable search
distance because, to our knowledge, the widest New York City street with a well-defined street
wall was Eastern Parkway in Brooklyn, with a building-to-building width of approximately
eighty meters along two consecutive blocks. The space between streetscape edges, identified by
the buffering procedure, defined the horizontal extent of each streetscape. Within these extents,
each streetscape was measured for seven variables by gathering attribute and aerial statistics
from building footprint and tree canopy layers (Table 1).

*Width* was the distance between opposing streetscape edges (Figure 4, A). Importantly,
this represented the distance between opposing building façades, the field of view for a user. It
should be noted that this is distinctly different from the curb-to-curb roadway width typically
used for geometric analyses. *Length* was the centerline length of the one-block street segment
(Figure 4, B). *Height* was the average height of buildings along the single edge, of the two edges
along each segment, with the taller average height (Figure 4, C). *Cross-sectional proportion*, the
quotient of height divided by width, described the interaction of these dimensions (Figure 4, D).
Narrow streets lined by tall buildings had large cross-sectional proportions, creating highly-
enclosed upright streetscapes, while wide streets lined by short buildings had small cross-
sectional proportions, creating shallow streetscapes with less enclosure. *Street wall continuity*
was the proportion of an edge that intersected a façade and thus formed a street wall (Figure 4,
E). For each segment, street wall continuity was reported only for the more continuous of the two
sides. *Buildings per length* was the count of buildings along both sides of a segment standardized
by centerline length (Figure 4, F). Tree canopy coverage was the proportion of area between edges that was covered by tree canopy (Figure 4, G). Streetscape design variables were measured as constants along entire block-length segments, no matter their lengths. Dividing segments into smaller, equal-length pieces might improve measurement precision but would substantially increase processing time, result in short “remainder” segments at block ends, and might not have revealed additional variability given the internal consistency in urban design along many blocks. The one-block unit has also been commonly used by other studies surveying urban design (13,15,16).

To control for potentially greater crash hazard presented by arterial streets designed to prioritize speed and traffic volume, each crash was also coded with a dummy variable denoting whether any intersecting street was classified as arterial according to US Census Feature Class Codes included in 2012 ESRI StreetMap centerline data. Crashes on or near arterials comprised 8.8% of the sample.

**TABLE 1 Streetscape Design Variable Descriptive Statistics**

<table>
<thead>
<tr>
<th>Streetscape Design Variable</th>
<th>Spatial Definition</th>
<th>Mean</th>
<th>Std. Dev.</th>
<th>Min.</th>
<th>Max.</th>
</tr>
</thead>
<tbody>
<tr>
<td>1 Width (meters)</td>
<td>Distance between edges (building-to-building across the street)</td>
<td>35.5</td>
<td>12.7</td>
<td>5.7</td>
<td>80.0</td>
</tr>
<tr>
<td>2 Length (meters)</td>
<td>Centerline distance between intersections</td>
<td>116.5</td>
<td>37.4</td>
<td>20.1</td>
<td>716.1</td>
</tr>
<tr>
<td>3 Height (meters)</td>
<td>Average building height, highest side</td>
<td>14.8</td>
<td>16.7</td>
<td>0.0</td>
<td>199.3</td>
</tr>
<tr>
<td>4 Cross-sectional proportion</td>
<td>Width (building-to-building)/Height on the highest side</td>
<td>0.658</td>
<td>0.870</td>
<td>0.000</td>
<td>16.793</td>
</tr>
<tr>
<td>5 Street wall continuity</td>
<td>Proportion of edge intersecting buildings on the more continuous side</td>
<td>0.613</td>
<td>0.173</td>
<td>0.000</td>
<td>1.000</td>
</tr>
<tr>
<td>6 Buildings per length</td>
<td>Count of buildings on both sides/Length</td>
<td>0.088</td>
<td>0.050</td>
<td>0.000</td>
<td>0.312</td>
</tr>
<tr>
<td>7 Tree canopy coverage</td>
<td>Proportion of street area covered by tree canopy</td>
<td>0.161</td>
<td>0.124</td>
<td>0.000</td>
<td>0.942</td>
</tr>
</tbody>
</table>
FIGURE 4 Streetscape Design Variables.
Modeling

Binary logistic regression with IBM SPSS Statistics 21 was used to examine whether the likelihood of a crash resulting in injury or death was affected by streetscape design variables and arterial classification. The model was appropriate for predicting the likelihood of binary crash outcomes with readily interpretable results. Our implementation estimated a constant and coefficients for each streetscape variable to maximize the likelihood of correctly predicting crash severity. Because logistic regression assumes predictor independence, and several of the streetscape design variables were calculated as a function of one another—cross-sectional proportion was, for instance, the quotient of height and width variables—two separate models were constructed to adhere to this assumption. Model A examined the effects of variables measuring streetscape size: width, length, and height. Model B examined the effects of variables accounting for streetscape proportions, particularly those related to enclosure: cross-sectional proportion, street wall continuity, buildings per length, and tree canopy coverage. Both models included the arterial street dummy variable. Model terms were judged for significance according to Wald Chi-Square tests with a P = 0.05 threshold for assumption of null hypothesis validity. Overall model fit was judged according to the Nagelkerke pseudo $R^2$.

RESULTS AND DISCUSSION

The results from both models (Table 2) support the premise that crashes on more enclosed, “human scale” streetscapes are less likely to be severe, while those on or at the intersection of arterial streets are more likely severe. Model A indicates small but significant effects among streetscape size variables. The odds of a given crash resulting in injury or death increase 0.5% for each additional meter of streetscape width. It is important to note that this width includes not just paved roadway, but shoulders and building setbacks that contribute to a streetscape’s visual field. Thus, a narrow roadway with buildings set back a substantial distance to either side would constitute a wide streetscape and would be more likely to foster severe crashes than a similar roadway with smaller building setbacks. Severe crashes are also less likely where blocks are shorter, likely as a result of reduced distance for vehicles to pick up speed between intersections. Each additional meter of block length increases the odds of a severe crash by 0.1%. Streetscape height, in contrast, shows a negative relationship. Each additional meter in the average height of buildings along the taller side of a streetscape lowers the odds of severe crashes by 0.2%. Thus, severe crashes are least likely on streetscapes that are tall and narrow with short block lengths. This finding is consistent with the premise that more constrained fields of view may improve safety outcomes by encouraging slower, less risky driving. It should be noted that field of view, in this case, refers to sight lines in all directions. As such, a streetscape might provide ample sight distance along the length of a roadway, allowing adequate detection of oncoming traffic hazards, while promoting caution through short sight lines that provide a sense of enclosure to either side.

Model B similarly demonstrates that proportions contributing to streetscape enclosure substantially affect crash severity. Each unit increase in cross-sectional proportion, the ratio of streetscape height to width, reduces the odds of severe crashes by nearly 9%. While the majority of streetscapes have cross-sectional proportions less than one, those in downtown areas may have proportions where the height of surrounding buildings exceeds the width by a factor of ten or more, nearly eliminating the likelihood of a severe crash according to the model. High street wall continuity similarly reduces the odds of severe crashes. Odds of severe crashes in streetscapes...
with highly continuous street walls are nearly 9% lower than in streetscapes with large spaces between buildings. This highlights the multifaceted capacity of infill development—filling holes in the urban fabric presented by vacant lots or relatively undeveloped spaces such as parking lots and gas stations—to improve traffic safety while simultaneously providing a more appealing public realm for pedestrians. Interestingly, while the number of buildings within a streetscape is cited as an important criteria for pedestrian appeal (13)—a greater number of buildings provides more opportunities for interesting stylistic variation—it has no significant effect on crash severity. Traffic safety appears to be affected only by basic size and proportions of streetscape design rather than more nuanced aspects of their design.

Enclosure due to tree canopy appears to have the largest implications for crash severity, indicating that natural resource management may have important and overlooked role in traffic safety and livability. Crashes on streetscapes fully covered by tree canopy are 51% less likely to result in injury or death than those on streetscapes without trees. While street trees require time and financial investment to plant, grow, and maintain in maturity, where they likely offer the most benefit, trees may offer an efficient option for improving streetscape enclosure along streets with few existing buildings or large setbacks. Infill building development is a complex and piecemeal process demanding cooperation among private landowners, financiers, and planning agencies. In contrast, tree planting and maintenance within public rights-of-way may be spearheaded by a comparatively small set of stakeholders and supported by urban forestry initiatives that already exist in many cities. It can take decades for trees to grow to maturity, but infrastructure for trees may be planned and installed along an entire street in a relatively short timeframe.

Both models indicate that crashes along or at intersections with arterial streets are approximately 20% more likely to result in injury or death compared with those away from arterials. This result is consistent with the assumption that greater vehicle speeds are associated with more severe crashes. Interestingly, the magnitude of effect from arterial classification, which is similar in both models, is not substantially greater than the counterbalancing effects offered by several streetscape design variables, chief among them tree canopy. If even 40% an arterial streetscape is covered by tree canopy, the result of just a few mature trees along a typical city block, this may offset the hazard presented by arterial classification. Increased propensity for severe crashes along urban arterials further substantiates the value of streetscape design to moderate crash risk in these places.

While the models indicate safety benefits can be gleaned from streetscape design, it is important to recognize that neither model predicts crash outcomes with any certainty. Both have Nagelkerke pseudo $R^2$ values less than 0.01 and classify 100% of crashes as property damage, resulting in approximately 27% classification error. Their lack of predictive power, even while model terms have highly significant effects, indicates the complexity of factors affecting crash outcomes. Factors that are most influential to crash severity, such as seat belt use, are often related to driver behavior and equipment rather than environmental conditions (30). Nonetheless, the models indicate that livable streetscape design contributes to traffic safety improvements, and should be considered alongside more traditional traffic safety countermeasures. At the very least, smaller and more enclosed streetscapes, which may be valuable to street livability in terms of walkability and economic development, should not be considered a traffic safety hazard. Combined land use and transportation planning in urban settings should challenge conventional wisdom about the necessity for wide, unobstructed roadside clear zones to promote traffic safety, making way for a more context-sensitive approach to designing livable arterial streetscapes.
TABLE 2 Binary Logistic Regression Modeling Results

MODEL A – Streetscape Size

Response: Crash Severity (1 = injury or death, 0 = property damage)

N = 244,689

<table>
<thead>
<tr>
<th>Predictors</th>
<th>β</th>
<th>Odds Ratio</th>
</tr>
</thead>
<tbody>
<tr>
<td>Width (meters)</td>
<td>0.005*</td>
<td>1.005</td>
</tr>
<tr>
<td>Length (meters)</td>
<td>0.001*</td>
<td>1.001</td>
</tr>
<tr>
<td>Height (meters)</td>
<td>-0.002*</td>
<td>0.998</td>
</tr>
<tr>
<td>Arterial (1 = arterial, 0 = non-arterial)</td>
<td>0.187*</td>
<td>1.205</td>
</tr>
<tr>
<td>Constant</td>
<td>-1.261*</td>
<td>0.283</td>
</tr>
</tbody>
</table>

Model Fit
-2 log likelihood: 285567.073
Nagelkerke R²: 0.003

MODEL B – Streetscape Proportions/Enclosure

Response: Crash Severity (1 = injury or death, 0 = property damage)

N = 244,689

<table>
<thead>
<tr>
<th>Predictors</th>
<th>β</th>
<th>Odds Ratio</th>
</tr>
</thead>
<tbody>
<tr>
<td>Cross-sectional proportion (ratio)</td>
<td>-0.093*</td>
<td>0.911</td>
</tr>
<tr>
<td>Street wall continuity (ratio)</td>
<td>-0.088*</td>
<td>0.916</td>
</tr>
<tr>
<td>Buildings per length (ratio)</td>
<td>-0.002†</td>
<td>0.988</td>
</tr>
<tr>
<td>Tree canopy coverage (ratio)</td>
<td>-0.711*</td>
<td>0.491</td>
</tr>
<tr>
<td>Arterial (1 = arterial, 0 = non-arterial)</td>
<td>0.167*</td>
<td>1.181</td>
</tr>
<tr>
<td>Constant</td>
<td>-0.777*</td>
<td>0.460</td>
</tr>
</tbody>
</table>

Model Fit
-2 log likelihood: 285333.383
Nagelkerke R²: 0.004

* P < 0.01
† P > 0.9

Results from this study should be interpreted with consideration for limitations inherent to the input data and modeling technique. Chiefly, the study only evaluates crashes and streetscapes within New York City because both types of data were readily accessible for this geography. While New York City includes impressive urban design heterogeneity, it is nonetheless one of the densest urban environments in the western hemisphere, with built environment, vehicle traffic, bicycling, and pedestrian characteristics that are unrepresentative of other cities, particularly newer, sprawling cities in the southern and southwestern United States.
Further research should gather appropriate data and extend analysis into cities with diverse urban form and traffic characteristics. Generalized measurement of urban design characteristics at crash sites also limits the precision of our results. The GIS-based streetscape measurement method provided novel efficiency and consistency, but could be improved to offer higher resolution measurements at more precise locations. Moreover, if crash data were more precisely located and included information about direction of travel, the analysis could account for urban design influences at more discrete locations rather than generalizing within a constant radius of each crash site.

Crash, building, and tree data used for analysis were subject to error in coding and spatial position. Crash data based on police reports may have incompletely described injuries from crashes involving many people. Spatial position of crashes may have also been imprecise or inconsistent due to various strategies—cross streets, street addresses, GPS coordinates—potentially used to report location. Building footprints and tree canopy areas were both drawn using automated and manual process, generalizing their shapes and introducing spatial inaccuracies through machine misinterpretation and human error. Streetscape design measurements were affected by these inaccuracies, though their overall impact on our analysis was likely small.

Logistic regression modeling of binary crash severity provided readily interpretable results but with limited precision. This modeling technique was prompted, in part, by the simplistic coding of crash data, which reported only injuries and deaths without nuanced severity information. With more specific injury data, future studies might discriminate between minor and severe injuries using ordinal models. They might also predict crash counts by location, or the count of injuries or deaths as an indicator of crash magnitude. These methods, however, would require accounting for exposure among vehicles, bicycles, and pedestrians, which is difficult to determine accurately for specific locations along a large sample of streets.

CONCLUSION

While traditional traffic safety suggests safety benefits from clear zones which are difficult to achieve in urban settings, our analysis suggests that crashes in urban contexts are less likely to be severe when they take place in smaller, more enclosed streetscapes. This finding is consistent with other studies proposing that speed is a primary factor in crash severity, especially in urban settings where there are complex traffic patterns and diverse road users, and that drivers operate at slower speeds when their field of vision is more constrained by smaller or more enclosed spaces (31–33). Identifying the safety benefits of smaller and enclosed streetscapes recasts streetscape design as an opportunity for constructive countermeasures rather than a hindrance to traditional safety engineering standards. Streetscape skeleton variables might even be considered as predictor variables for crash modification models such as those contained in the Highway Safety Manual (34).

Safety benefits offered by specific characteristics of streetscape design can only be adequately identified with precise measurement of a large number of streetscapes where crashes have occurred. This study uses an efficient, GIS-based method to capture streetscape design measurements along tens of thousands of city blocks, allowing expedient assessment of a suite of design variables at the locations of tens of thousands of crashes. Compared with previous studies drawing on land use or roadway characteristics as generalized indicators of “human scale” or enclosed streetscapes, this strategy unpacks the contribution of specific design characteristics to safety outcomes. Understanding how variables such as streetscape width, street wall continuity,
and tree canopy coverage can reduce propensity for severe crashes may help planners make recommendations that are readily translated into design practice. There is a need to improve livability along urban arterials that are challenged to provide high levels of service for vehicular traffic while maintaining a safe and attractive environment for non-vehicular users and commercial activity. To reduce crash severity, planners may promote infill development that creates smaller, more enclosed streetscapes with greater street wall continuity, taller buildings, and narrower setbacks. Dense built environments, however, often take decades to develop. In the short term, street tree planting and maintenance may be the most efficient approach to creating more enclosed streetscapes. Even small trees, planted close together, may provide a sense of enclosure along a roadway. Trees can be installed relatively efficiently, often on public land, under the direction of municipal agencies. Moreover, infill development and street trees are consistent with livability goals such as place making, walkability, destination accessibility, and provision of natural amenities. By demonstrating that small and enclosed urban streetscapes are also a traffic safety asset, this study opens the door to countermeasure design that aligns with other aspects of livability planning and can help urban arterials comfortably accommodate their diverse roles.
REFERENCES


