The Relationship between Community Design and Crashes Involving Older Drivers and Pedestrians

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The Relationship between Community Design and Crashes Involving Older Drivers and Pedestrians

Eric Dumbaugh1 and Yi Zhang2

Abstract
This study uses negative binomial regression models to understand how urban form may affect total and KSI (killed or seriously injured) crashes involving drivers and pedestrians aged seventy-five and older. Intersections, strip commercial establishments, big box stores, and arterial thoroughfares were associated with increases in crashes involving older motorists, while big box stores and arterials increased crashes for older pedestrians. Networks of lower-speed streets were associated with fewer crashes involving older motorists and pedestrians. This study concludes by detailing community design considerations that may enhance the safety of older motorists and pedestrians

Keywords
design, urban form, transportation, neighborhood planning

Introduction
The aging population of the United States increases the importance of ensuring safe mobility options for older adults. Despite the growing awareness of this need, little attention has been given to the relationship between the built environment and the incidence of traffic-related crashes, injuries, and deaths involving older drivers. Most studies relating to traffic safety and older adults focus either on age-related declines in motor performance abilities (for comprehensive reviews, see Dewar 2002; Owsley 2004), or on the pre-crash behaviors that result in crashes involving older drivers (Hakamies-Blomqvist 2004; Hallmark and Mueller 2004; Smiley 2004; Straight 1997; Wasielewski 1984). Indeed, a recent review of the relationship between the built environment and crash incidence involving older adults did not yield a single study that examined how community design, or the configuration of land uses and street networks, may be associated with traffic-related crashes, injuries, or deaths involving this user group (Dumbaugh 2008).

This study seeks to fill this void in the literature. It begins by summarizing both the historical basis for the current professional assumptions on “safe” community design, as well as the existing literature on the subject. It then presents negative binomial regression models that examine the association between community design and crash incidence involving pedestrians, cyclists, and motorists older than age seventy-five years in the San Antonio metropolitan area.

The Basis of Contemporary Community Design
The flood of automobile traffic into American cities during the early twentieth century brought with it traffic-related deaths and injuries, making traffic safety a major public health concern, and leading to a widespread movement to address the growing perils of automobile traffic. Of particular concern was the need to protect families and children, who were depicted as innocent victims of a growing automobile menace (Norton 2008). While this safety reform movement influenced numerous facets of American life, ranging from the adoption of traffic laws to the design of devices for managing right of way at intersections, one of its most profound effects was on community design.

Reforms in the area of safe community design were first outlined by Clarence Perry, who developed the concept of the neighborhood unit, intended as a neighborhood large enough to sustain a community elementary school—in his estimate,
about six thousand persons (see Figure 1). The safety of children would be addressed by reconfiguring communities to prevent the intrusion of traffic into residential areas. This was to be accomplished by redesigning the street network into a functional hierarchy. Large, traffic-carrying streets (the progenitor to the modern surface arterial) would be located on the boundaries of a community, while the local street network would be reconfigured to eliminate direct routes through the neighborhood and designing local streets to be as narrow as possible. To further eliminate cut-through traffic in the neighborhood, retail, commercial, and other uses would be removed from the neighborhood’s boundaries, and relocated onto major roadways bounding the neighborhood unit (Perry 1939).

The major shortcoming of Perry’s proposal was that it failed to ensure that traffic remained on the arterials, away from residential streets. The architects Clarence Stein and Henry Wright sought to remedy this deficiency with the design of Radburn, which was designed to eliminate residential cut-through traffic entirely through the use of residential cul-de-sacs (Figure 2). While Radburn was a commercial failure (Stein 1957), the design concepts it embodied were codified into design guidance issued by the Federal Housing Administration (FHA 1936), which was in turn used to identify projects eligible for FHA mortgage insurance. These ideas were further embedded into subdivision controls that were being adopted by municipalities. As such, these design ideas have influenced not only the financial practices that directed the construction of new developments but also the land use regulations that authorized the developments to be built in the first place. Stated another way, the result was “the shaping of suburbia” (Southworth and Ben-Joseph 1995).

Despite the widespread adoption of disconnected residential subdivisions, there has been surprisingly little examination of their effects on crash incidence, and none that has explicitly examined its impacts on older adults. The earliest study to examine the issue was a 1957 publication by Harold Marks, which reported that new “limited access” communities—that is, disconnected residential subdivisions—reported fewer crashes than older “grid iron” neighborhoods. In 1995, Eran Ben-Joseph followed up on Marks’s original work and found that even after controlling for traffic volumes, cul-de-sac neighborhoods likewise reported fewer crashes than gridded neighborhoods. Nonetheless, a major
shortcoming of these studies is they only examined crash incidence on local streets and did not account for the possibility that, by relocating traffic and retail uses to arterial thoroughfares, these communities may simply be shifting crashes from within a community to the arterials that bound it.

Dumbaugh and Rae (2009) sought to address this issue by examining crash incidence at the block group level for the City of San Antonio. They found that the major predictors of urban crash incidence were arterials, strip commercial uses, and big box stores—precisely the types of streets and land uses that had been adopted to reduce crashes on residential streets. Alternatively, neighborhood-scaled retail uses, defined as commercial or retail uses of 20,000 square feet or less, but developed at floor-area ratios (FARs) of 1 or greater, were associated with significant reductions in both total and injurious crashes. A follow-up study by Dumbaugh and Li (2011) determined that these findings held true for crashes involving pedestrians and motorists alike. These studies, while instructive for understanding the role of community design on crash incidence, examined crashes for all age groups. They did not consider the needs of specific subpopulations, such as children or the elderly, who may have unique

Figure 2. Radburn (Stein 1957).
travel patterns or abilities that may place them disproportionately at risk in certain types of environments.

**Modeling Crashes Involving Older Adults**

Given the absence of meaningful information on the relationship between the built environment and crashes involving older pedestrians and motorists, we sought to determine whether these findings held true for older adults. To do so, we collected crash data for the 2003–2007 period from the Texas Department of Transportation (TxDOT) and integrated them into a GIS-based database of crash incidence and urban form. In addition to crash data, this database includes parcel-level land use information supplied by the Bexar County Tax Appraisal District, street network information acquired from the San Antonio–Bexar County Metropolitan Planning Organization, information on traffic volumes obtained from the City of San Antonio and TxDOT, and demographic information acquired from the U.S. Census. Collectively, these data allow us to examine the spatial distribution of crashes in conjunction with both traffic volumes and the built environment.

Because we were interested in crashes occurring in urban areas, rather than rural ones, we sought to exclude those block groups in the region that had primarily rural characteristics. While we considered a number of measures for determining what constituted an “urban” block group, the region’s highway infrastructure effectively bounds the majority of the population and development for the San Antonio region, and was the boundary used for classifying an area as urban. The study area for this analysis ultimately consisted of the 938 block groups located within the 1604 loop to the north, and I-410 to the south (see Figure 3). The majority of the region’s surface transportation network is contained within our study area, as are 1.2 million of the 1.4 million people living in Bexar County in 2000.

**Dependent Variables**

Using these data, we sought to identify the factors associated with crashes involving older motorists, pedestrians, and cyclists. While there are varying means of operationalizing what constitutes an older adult, we defined an older adult as being a driver, pedestrian, or cyclist aged seventy-five or older. The seventy-five- and older cohort was selected for specific examination because it is at this age that older adults begin to report substantially higher rates of traffic fatalities and injuries, at least when considered on a per-mile-traveled basis (Hakamies-Blomqvist 2004). As such, it is intended to shed light on the design factors associated with the population at greatest risk of being involved in a traffic-related injury or death.

Between 2003 and 2007, there were 26,751 crashes involving adults aged seventy-five and older, of which nearly 3,600, or 13 percent, resulted in their injury or death (see Table 1). It is important to observe that nearly all of the crashes involving older pedestrians and cyclists resulted in an injury or death. Despite accounting for less than 1 percent of total crashes, pedestrians and cyclists accounted for more than 5 percent of the total injuries, and nearly 30 percent of the total fatalities.

Given the small numbers of cyclist and fatal crashes, we combined them with pedestrian and injurious crashes, respectively. The dependent variables are total and KSI (killed or seriously injured) crashes involving older drivers and older nonmotorists. Because the dependent variables are count data that are overdispersed (i.e., the variance is greater than the mean), negative binomial regression models are used for the following analysis. The model coefficients report the percentage change of the dependent variable that occurs with each unit of change in the independent variable (Hilbe 2007). It is important to expressly note that this study examines crash counts, rather than crash rates (total crashes divided by traffic volumes). The reason for this operational decision is that crash rates have proven unreliable when used in regression models (Miaou and Lum 1993). Nonetheless, traffic volumes are an important contributing factor for understanding crash incidence, as more crashes may be associated with increased exposure. To account for the influence of traffic volumes on block group–level crash incidence, we have included millions of vehicle miles traveled (MVMT) as a control variable.

**Modeling the Relationship between Crash Incidence and Urban Form**

Examining how environmental factors may influence crash incidence requires several methodological decisions. The first entails determining an appropriate unit of analysis. Most conventional safety studies focus on crash incidence at the level of the street segment. This is based on the assumption that roadway traffic volumes and geometric features are sufficient for understanding urban crash incidence. This study, however, seeks to understand how characteristics of the built environment may be associated with specific crash patterns, thus requiring information on the developmental context in which crashes occurred. To do so, we opted to analyze small geographic areas rather than individual street segments.

Two related decisions pertained to how we were to delineate the boundaries of these areas, as well as how we were to deal with information occurring along their edges. We used census block group boundaries to define the smaller areas, thus allowing us to capture accurate information on the population of these areas. To ensure that we captured information occurring on the boundaries of these block groups, as well as to address any micro-level spatial variation that may exist in the definition of our GIS layers, we created a 200-foot buffer around each block group (roughly the width of a fully designed principal arterial), and aggregated information on crashes and traffic volumes to the buffer area. While such an approach results in some streets and crashes being assigned to more than one neighborhood, it is
important to reiterate that the unit of the analysis is the block group, not the individual street or crash location. This operational decision provides a consistent framework for addressing problems associated with differences in the spatial definition of individual GIS layers, while also ensuring that essential information on crash incidence was not lost due to the means by which the unit of analysis was operationalized.

**Independent Variables**

To analyze the relationship between community design and crash incidence, we included the following variables in our analysis:

- **Block group acreage.** Census block groups vary in size, with larger block groups typically located at the periphery of a metropolitan area, in areas that are predominantly residential in character and are likely to export much of their traffic to other, more central locations. To control for whatever statistical effects block group definitions might have on our results, we included block group acreage as a control variable.

- **Millions of vehicle miles traveled.** Because heavier traffic volumes can create more opportunities for crashes to occur, we sought to control for the effects of VMT on crash incidence. TxDOT provided us with average daily traffic volumes (ADT) for all

![Figure 3. San Antonio–Bexar County study area.](image)
state highways (freeways and principal arterials) in the metropolitan area. The City of San Antonio also gave us traffic counts at 804 locations not on the state highway system. Taken together, we had data for all freeways, principal arterials, minor arterials, and collector roadways in the region. Because the state provided ADT for roadway segments and the city provided ADT for single points, we made the two compatible by assuming that point ADT remained the same along a road segment for half the distance to the next data point, where we assumed it changed to the ADT recorded for the next data point.

It was also necessary to subdivide roadway segments so they did not cross block group boundaries. For this purpose we again used a 200-foot buffer around each block group in order to include all related roadways in the analysis. Once the road segments were subdivided, we calculated VMT for each road segment by multiplying that segment’s ADT by its length, and then multiplying this value by 365 days and 5 years. We then determined the block group–level VMT by summing the VMT for all of the individual road segments in the block group and dividing the sum by one million. The resulting value is block group–level VMT, in millions.

- **Population aged seventy-five and older.** Because the number of older adults in a block group may influence local crash incidence, we included the number of persons aged seventy-five and older as a control variable.
- **Intersection counts.** Intersections create locations where opposing streams of traffic cross, and thus locations where conflicts between roadway users may emerge. Previous research has found that a substantial portion of crashes involving older adults tend to occur at intersections, particularly when older adults attempt to turn left across multiple lanes of traffic (Hauer 1988; Kloeppep et al. 1995; Partyka 1983; Preussler et al. 1998). This variable is the count of intersections in a block group.
- **Strip commercial uses.** While intersections have been found to be problematic for older adults, little attention has been given to potential hazards posed by land development configurations. Strip commercial uses typically have direct driveway access to an adjacent arterial thoroughfare, thus creating an informal intersection location that may create a crash risk location for older adults. This variable is measured as the count of commercial and retail establishments located adjacent to an arterial thoroughfare.
- **Big box stores.** Big box stores are major trip attractors that can draw traffic from a large geographic area. Given their size, they also generate a good deal of off-street traffic, as vehicles circulate through the parcel in search of parking and as pedestrians attempt to walk from their cars to the building. For this study, a “big-box” store is identified as a retail use composed of 50,000 square feet or more, and having an FAR of 0.4 or less (i.e., more surface parking than building area). This variable is the sum of these establishments within a block group’s boundaries.
- **Pedestrian-scaled retail uses.** Pedestrian advocates generally encourage the adoption of more “traditional” retail configurations, where buildings are aligned to the street, rather than set back by a large parking lot. Recent research has found the presence of such uses to be associated with both lower vehicle speeds (Ivan, Garrick, and Hanson 2009) and reduced crash incidence (Dumbaugh and Rae 2009). Nonetheless, there has been little examination into how such uses may influence the safety of older adults. To determine whether such uses may be beneficial, the count of such establishments were included as an independent variable in the models. Pedestrian-scaled retail uses are defined as a commercial or retail uses of 20,000 square feet or less, but developed at FARs of 1 or greater (i.e., buildings that front the street or otherwise have little undeveloped surface space on the lot). The resulting variable is the count of such establishments in a neighborhood, and serves as a rough indicator of a neighborhood’s “urbanism” (see Figure 4).
- **Miles of arterials.** Conventional community design practice seeks to channel all nonresidential traffic onto arterial thoroughfares, which are intended to accommodate higher-speed automobile traffic in a “safe and efficient” manner. Age-related declines in

### Table 1. Crashes Involving Older Adults, 2003–2007.

<table>
<thead>
<tr>
<th></th>
<th>Total</th>
<th>KSI</th>
<th>Injured</th>
<th>Killed</th>
</tr>
</thead>
<tbody>
<tr>
<td>Driver</td>
<td>26,533</td>
<td>3,361</td>
<td>3,308</td>
<td>53</td>
</tr>
<tr>
<td>Nonmotorized</td>
<td>218</td>
<td>215</td>
<td>193</td>
<td>22</td>
</tr>
<tr>
<td>Pedestrian</td>
<td>202</td>
<td>199</td>
<td>179</td>
<td>20</td>
</tr>
<tr>
<td>Cyclist</td>
<td>16</td>
<td>16</td>
<td>14</td>
<td>2</td>
</tr>
<tr>
<td>Total</td>
<td>26,751</td>
<td>3,576</td>
<td>3,501</td>
<td>75</td>
</tr>
</tbody>
</table>

Note: KSI = killed or seriously injured.
visual acuity make it difficult for older adults to estimate the time-to-impact of oncoming vehicles traveling at higher speeds (Smiley 2004; Wasielewski 1984). Older drivers are generally able to identify safe gaps in traffic when oncoming vehicles are traveling at speeds of 30 miles/hour or less, but they have increasing difficulty doing so when vehicles are traveling at higher speeds (Chandraratna, Mitchell, and Stamatiadis 2002; Scialfa et al. 1991; Staplin 1995). As such, the higher speeds for which arterials are designed may exacerbate the crash hazards experienced by older adults. Likewise, arterial thoroughfares have been found to be associated with increases in the frequency (Garder 2001, 2004) and severity (Anderson et al. 1997; Durkin and Pheby 1992) of crashes involving pedestrians. As such, one would expect these facilities to have a detrimental effect on the safety of older drivers and pedestrians alike. This variable is the centerline miles of arterial thoroughfare located within the block group.

- **Density of lower-speed streets.** Given the general caution exercised by older adults as both drivers and pedestrians, a recent review hypothesized that the safety of older adults would likely be enhanced by the presence of a lower-speed network of streets that would allow older adults to forego using arterials (Dumbaugh 2008). To examine this hypothesis, this study included a measure of the density of local and collector streets within a block group. Local and collector roadways are typically designed for speeds between 20 and 35 miles/hour, speeds that not only are compatible with the driving abilities of older adults but also reduce stopping sight distances, thus allowing other motorists to brake quickly should they encounter an older motorist or pedestrian in the right-of-way. Block groups with a dense network of lower-speed streets would be expected to provide a greater number of lower-speed routes that older adults can use, and would thus be expected to be associated with a significant decrease in crash incidence. This measure is the total mileage of local and collector roadways in a block group, divided by the number of acres. To simplify the interpretation of the coefficient, we divided the number of acres in the block group by 100. The corresponding measure thus reports the safety effect of each mile of lower-speed street per 100 acres (see Figure 5).

### Crashes Involving Older Drivers

Tables 2 and 3 present the models for total and KSI crashes involving older drivers. All of the variables entered at statistically significant levels, and with the expected signs. After controlling for MVMT and the number of persons aged seventy-five and older in a block group, the number of intersections proved to be associated with an increase in crashes involving older drivers, with each intersection in a block group being associated with a 0.4 percent increase in total crashes, and a 0.2 percent increase in KSI crashes. This proved to be minor in comparison with strip commercial uses and big box stores. Each strip commercial use was associated with a 2.5 and 1.9 percent increase in total and KSI crashes, respectively, while each big box store was associated with a 7.2 and 3.9 percent increase in these crash types. Conversely, pedestrian-scaled retail uses were associated with significant crash reductions, with each such use corresponding to a 2.9 percent decrease in total crashes and 3.3 percent decrease in...
KSI crashes. Arterial thoroughfares proved to be a major risk factor, with each mile of arterial thoroughfare corresponding with a 9 percent increase in total crashes and a 9.7 percent increase in KSI crashes. The presence of a concentration of lower-speed streets proved to offset this risk, with each mile of local or collector roadway per 100 acres being associated with an 11.7 percent reduction in total crashes, and a 13.7 percent reduction in KSI crashes.

Figure 5. Street network density: the suburban block group at top has a street density of 2.58, while the urban block at bottom has a street density of 3.90.
Tables 4 and 5 present the models for total and KSI crashes involving older pedestrians and cyclists. Given that many walking and cycling trips are likely to originate from home, it is unsurprising that the number of older adults in a community is related to an increased incidence of pedestrian and cyclist crashes. Interestingly, neither of the variables that are typically associated with higher rates of walking and cycling—the number of intersections and the number of pedestrian-scaled retail uses in a community—proved to be significantly related to either total or KSI crashes involving older pedestrians and cyclists. Further, the presence of a dense network of lower speed streets was associated with significant reductions in KSI pedestrian and cyclist crashes, and near-significant reductions into total crashes.

Arterial thoroughfares and big box stores, two features of suburban environments, were associated with significant increases in crashes involving older pedestrians and cyclists. Each mile of arterial thoroughfare was associated with a 28 percent increase in total and KSI crashes, while each big box store was associated with an 8.6 percent increase in these crash types.

### Tables 2 and 3

<table>
<thead>
<tr>
<th>Table 2. Total Crashes Involving Older Drivers.</th>
<th>Coefficient</th>
<th>z</th>
<th>p</th>
<th>95% Confidence Interval</th>
</tr>
</thead>
<tbody>
<tr>
<td>Constant</td>
<td>2.5903</td>
<td>26.540</td>
<td>0.000</td>
<td>2.3990 to 2.7816</td>
</tr>
<tr>
<td>Block group acreage</td>
<td>−0.0009</td>
<td>−6.900</td>
<td>0.000</td>
<td>−0.0011 to −0.0006</td>
</tr>
<tr>
<td>MVMT</td>
<td>0.0025</td>
<td>9.040</td>
<td>0.000</td>
<td>0.0019 to 0.0030</td>
</tr>
<tr>
<td>Population 75 and older</td>
<td>0.0033</td>
<td>7.180</td>
<td>0.000</td>
<td>0.0024 to 0.0041</td>
</tr>
<tr>
<td>No. of intersections</td>
<td>0.0044</td>
<td>3.990</td>
<td>0.000</td>
<td>0.0023 to 0.0066</td>
</tr>
<tr>
<td>No. of strip commercial uses</td>
<td>0.0254</td>
<td>9.010</td>
<td>0.000</td>
<td>0.0198 to 0.0309</td>
</tr>
<tr>
<td>No. of big box stores</td>
<td>0.0716</td>
<td>3.860</td>
<td>0.000</td>
<td>0.0352 to 0.1080</td>
</tr>
<tr>
<td>No. of pedestrian-scaled retail uses</td>
<td>−0.0292</td>
<td>−3.720</td>
<td>0.000</td>
<td>−0.0445 to −0.0138</td>
</tr>
<tr>
<td>Miles of surface arterials</td>
<td>0.0902</td>
<td>3.100</td>
<td>0.002</td>
<td>0.0332 to 0.1473</td>
</tr>
<tr>
<td>Density of lower-speed streets</td>
<td>−0.1165</td>
<td>−5.610</td>
<td>0.000</td>
<td>−0.1573 to −0.0758</td>
</tr>
</tbody>
</table>

Note: N = 938; log likelihood = −3,744; χ² = 684 (0.000). MVMT = millions of vehicle miles traveled.

<table>
<thead>
<tr>
<th>Table 3. KSI Crashes Involving Older Drivers.</th>
<th>Coefficient</th>
<th>z</th>
<th>p</th>
<th>95% Confidence Interval</th>
</tr>
</thead>
<tbody>
<tr>
<td>Constant</td>
<td>0.9155</td>
<td>8.230</td>
<td>0.000</td>
<td>0.6976 to 1.1334</td>
</tr>
<tr>
<td>Block group acreage</td>
<td>−0.0007</td>
<td>−4.530</td>
<td>0.000</td>
<td>−0.0010 to −0.0004</td>
</tr>
<tr>
<td>MVMT</td>
<td>0.0022</td>
<td>7.200</td>
<td>0.000</td>
<td>0.0016 to 0.0027</td>
</tr>
<tr>
<td>Population 75 and older</td>
<td>0.0020</td>
<td>4.770</td>
<td>0.000</td>
<td>0.0012 to 0.0028</td>
</tr>
<tr>
<td>No. of intersections</td>
<td>0.0023</td>
<td>1.650</td>
<td>0.098</td>
<td>−0.0004 to 0.0050</td>
</tr>
<tr>
<td>No. of strip commercial uses</td>
<td>0.0199</td>
<td>6.820</td>
<td>0.000</td>
<td>0.0142 to 0.0257</td>
</tr>
<tr>
<td>No. of big box stores</td>
<td>0.0387</td>
<td>2.150</td>
<td>0.031</td>
<td>0.0035 to 0.0739</td>
</tr>
<tr>
<td>No. of pedestrian-scaled retail uses</td>
<td>−0.0327</td>
<td>−3.900</td>
<td>0.000</td>
<td>−0.0491 to −0.0163</td>
</tr>
<tr>
<td>Miles of surface arterials</td>
<td>0.0965</td>
<td>3.250</td>
<td>0.001</td>
<td>0.0383 to 0.1546</td>
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<tr>
<td>Density of lower-speed streets</td>
<td>−0.1366</td>
<td>−5.240</td>
<td>0.000</td>
<td>−0.1877 to −0.0856</td>
</tr>
</tbody>
</table>

Note: N = 938; log likelihood = −2,024; χ² = 446 (0.000). KSI = killed or seriously injured; MVMT = millions of vehicle miles traveled.

### Crashes Involving Older Pedestrians and Cyclists

Tables 4 and 5 present the models for total and KSI crashes involving older pedestrians and cyclists. Given that many walking and cycling trips are likely to originate from home, it is unsurprising that the number of older adults in a community is related to an increased incidence of pedestrian and cyclist crashes. Interestingly, neither of the variables that are typically associated with higher rates of walking and cycling—the number of intersections and the number of pedestrian-scaled retail uses in a community—proved to be significantly related to either total or KSI crashes involving older pedestrians and cyclists. Further, the presence of a dense network of lower speed streets was associated with significant reductions in KSI pedestrian and cyclist crashes, and near-significant reductions into total crashes.

Arterial thoroughfares and big box stores, two features of suburban environments, were associated with significant increases in crashes involving older pedestrians and cyclists. Each mile of arterial thoroughfare was associated with a 28 percent increase in total and KSI crashes, while each big box store was associated with an 8.6 percent increase in these crash types.

### Implications for Community Design Practice

Considered as a whole, the results of this study suggest that conventional community design practice, which redirects automobile traffic away from residential areas and onto arterials, may be problematic for older adults. Community design may be made more accommodating to older adults through modifications to the configuration of street networks, the design of safe intersections, and the location and configuration of retail and commercial uses. Each is addressed below.

### Network Configuration

Whether they are traveling as drivers or pedestrians, older adults have a difficult time negotiating through traffic moving at high speeds. The hierarchical street networks and single-use characteristics of conventional community design practice seek to channel traffic onto arterial thoroughfares, thus forcing older adults to travel on precisely the types of roads for which they are often least equipped. The result is a significant increase in traffic-related crashes, injuries, and deaths. Each mile of arterial thoroughfare is associated with
a 10 percent increase in crashes involving older drivers, and a 28 percent increase in crashes and injuries involving older pedestrians, nearly all of which involves a serious injury or death.

Rather than addressing the inherent safety problems such environments create for older adults, the conventional approach is to presume that such problems are largely attributable to a decline in driving abilities associated with aging. Such explanations are misleading. Older adults are more cautious than younger drivers precisely because of these age-related declines in visual acuity and reaction times, leading them to avoid traveling on routes that they feel are poorly matched to their abilities. As revealed in a survey sponsored by the American Association of Retired Persons, older drivers often forego driving at night, during congested time periods, and when possible, along higher-speed roadways. Nonetheless, a majority of older adults (90 percent) report feeling comfortable driving along lower-speed, two-lane routes (Straight 1997). The presence of a dense network of such routes is associated with a decline in significant decline in crashes involving older motorists and pedestrians alike. Each additional mile of such roadway per 100 acres is associated with an 11.7 percent decrease in total crashes involving older drivers, and a 13.6 percent decrease in KSI crashes. They also resulted in a 13 percent reduction in both total and KSI crashes involving older pedestrians and cyclists. In short, the presence of a connected network of lower-speed routes would appear to go a long way to enhance the safety of older adults.

### Intersections

A potential downside of increased street network connectivity is that it leads to the creation of additional intersections, which previous research has identified as being problematic for older drivers (Hakamies-Blomqvist 2004; Hallmark and Mueller 2004; Matthias, De Nicholas, and Thomas 1996; Smiley 2004; Straight 1997; Wasielewski 1984). And indeed, this study found that intersections were associated with a significant increase in both total and KSI crashes involving older pedestrians and cyclists. In short, the presence of a connected network of lower-speed routes would appear to go a long way to enhance the safety of older adults.

### Table 4. Crashes Involving Older Pedestrians and Cyclists.

<table>
<thead>
<tr>
<th></th>
<th>Coefficient</th>
<th>z</th>
<th>p</th>
<th>95% Confidence Interval</th>
</tr>
</thead>
<tbody>
<tr>
<td>Constant</td>
<td>−1.6295</td>
<td>−5.040</td>
<td>0.000</td>
<td>−2.2629 −0.9961</td>
</tr>
<tr>
<td>Block group acreage</td>
<td>−0.0026</td>
<td>−3.820</td>
<td>0.000</td>
<td>−0.0039 −0.0012</td>
</tr>
<tr>
<td>MVMT</td>
<td>0.0010</td>
<td>1.030</td>
<td>0.301</td>
<td>−0.0009 0.0029</td>
</tr>
<tr>
<td>Population 75 and older</td>
<td>0.0020</td>
<td>1.990</td>
<td>0.046</td>
<td>0.0000 0.0041</td>
</tr>
<tr>
<td>No. of intersections</td>
<td>0.0053</td>
<td>1.020</td>
<td>0.307</td>
<td>−0.0048 0.0154</td>
</tr>
<tr>
<td>No. of strip commercial uses</td>
<td>0.0075</td>
<td>0.880</td>
<td>0.379</td>
<td>−0.0092 0.0241</td>
</tr>
<tr>
<td>No. of big box stores</td>
<td>0.0863</td>
<td>1.850</td>
<td>0.065</td>
<td>−0.0053 0.1780</td>
</tr>
<tr>
<td>No. of pedestrian-scaled retail uses</td>
<td>0.0045</td>
<td>0.240</td>
<td>0.811</td>
<td>−0.0326 0.0417</td>
</tr>
<tr>
<td>Miles of surface arterials</td>
<td>0.2828</td>
<td>2.960</td>
<td>0.003</td>
<td>0.0957 0.4698</td>
</tr>
<tr>
<td>Density of lower-speed streets</td>
<td>−0.1288</td>
<td>−1.630</td>
<td>0.102</td>
<td>−0.2832 0.0257</td>
</tr>
</tbody>
</table>

Note: n = 938; log likelihood = −520; χ² = 69 (0.000). MVMT = millions of vehicle miles traveled.

### Table 5. KSI Crashes Involving Older Pedestrians and Cyclists.

<table>
<thead>
<tr>
<th></th>
<th>Coefficient</th>
<th>z</th>
<th>p</th>
<th>95% Confidence Interval</th>
</tr>
</thead>
<tbody>
<tr>
<td>Constant</td>
<td>−1.6078</td>
<td>−5.020</td>
<td>0.000</td>
<td>−2.2355 −0.9801</td>
</tr>
<tr>
<td>Block group acreage</td>
<td>−0.0025</td>
<td>−3.810</td>
<td>0.000</td>
<td>−0.0038 −0.0012</td>
</tr>
<tr>
<td>MVMT</td>
<td>0.0010</td>
<td>1.100</td>
<td>0.270</td>
<td>−0.0008 0.0029</td>
</tr>
<tr>
<td>Population 75 and older</td>
<td>0.0019</td>
<td>1.920</td>
<td>0.055</td>
<td>0.0000 0.0039</td>
</tr>
<tr>
<td>No. of intersections</td>
<td>0.0048</td>
<td>0.940</td>
<td>0.346</td>
<td>−0.0052 0.0147</td>
</tr>
<tr>
<td>No. of strip commercial uses</td>
<td>0.0076</td>
<td>0.920</td>
<td>0.359</td>
<td>−0.0087 0.0240</td>
</tr>
<tr>
<td>No. of big box stores</td>
<td>0.0856</td>
<td>1.880</td>
<td>0.061</td>
<td>−0.0038 0.1751</td>
</tr>
<tr>
<td>No. of pedestrian-scaled retail uses</td>
<td>0.0060</td>
<td>0.330</td>
<td>0.745</td>
<td>−0.0301 0.0421</td>
</tr>
<tr>
<td>Miles of surface arterials</td>
<td>0.2789</td>
<td>2.980</td>
<td>0.003</td>
<td>0.0957 0.4621</td>
</tr>
<tr>
<td>Density of lower-speed streets</td>
<td>−0.1351</td>
<td>−1.720</td>
<td>0.086</td>
<td>−0.2892 0.0189</td>
</tr>
</tbody>
</table>

Note: n = 938; log likelihood = −515; χ² = 71 (0.000). KSI = killed or seriously injured; MVMT = millions of vehicle miles traveled.
Even downtown Portland Oregon, which has 200-foot-long blocks and thus one of the densest concentrations of intersections in the world (Jacobs 1993), is nevertheless only able to squeeze in about 20 intersections per linear mile of roadway (see Figure 6, below). Stated another way, the results of this study suggest that the benefits of having a network of lower-speed streets greatly outweighs any safety risk that may be associated with more frequent intersections.

The configuration of lower-speed networks may further reduce the incidence of intersection-related crashes for older adults, since much of the problem older adults encounter at intersections stems from an inability to adequately judge the time-to-impact from oncoming traffic. Older adults have less of a problem at the lower speeds found on local and collector routes (Chandraratna, Mitchell, and Stamatiadis 2002; Matthias, De Nicholas, and Thomas 1996; Staplin 1995; Yi 1996). In fact, older adults have been even observed to overestimate time-to-impact at lower speeds (Scialfa et al. 1991), a fact that would lead older adults to increase their margin of safety when attempting to negotiate an intersection. In short, one would expect intersections located along lower-speed street networks to report fewer crashes, on average, than those found on higher-speed streets.

While intersections remain a problem for older adults, this may be addressed through the use of more senior-friendly intersection control. Conventional engineering practice tends to prioritize vehicle throughput along major thoroughfares through the use of such features as permitted left-turn phasing, permitted right-turns-on-red, and the avoidance of four-way stop control at intersections. Collectively, these result in older adults being forced to turn or cross roadways at unprotected locations. Authors examining the subject uniformly recommend increasing protected crossings, most notably the use of protected-only left-turn phasing at signalized intersections (Chandraratna, Mitchell, and Stamatiadis 2002; Hallmark and Mueller 2004; Matthias, De Nicholas, and Thomas 1996; Staplin et al. 1998; Ulfarsson, Kim, and Lentz 2006). Stated another way, the hazards encountered by older drivers at intersections can likely be remedied through intersection control that prioritizes safety rather than throughput.

This study did not find intersections to be significantly related to the incidence of crashes involving older pedestrians, although the variable did enter the models positively. The problem is probably not just the difficulty that older pedestrians have with intersections per se but instead problems that emerge when older pedestrians are forced to cross higher-speed roadways. Given that older adults are less likely than younger cohorts to cross the street at nonintersection locations, the logical conclusion is that older adults are being struck while crossing arterials at intersection locations. Nonetheless, future research is needed in this area.

**Location and Configuration of Retail and Commercial Uses**

Like intersections, driveways associated with strip commercial uses and big box stores create locations where traffic...
streams are likely to conflict, and like intersections, they proved to be locations where crashes involving older motorists were likely to occur. Each strip commercial establishment posed between 6 and 8 times the crash risk to older adults as does the typical intersection, and each big box store posed 17 times the crash risk. This is not surprising. These uses tend to locate along arterials and higher-volume traffic routes, and thus create locations where older drivers are more likely to interact with higher-speed traffic at locations that are unprotected by a traffic signal.

While strip commercial and big box stores are problematic for older drivers, this did not prove to be the case with pedestrian-scaled retail uses, which were associated with significant reductions in crashes involving older drivers. Each pedestrian-scaled retail use was associated with a 3.7 percent reduction in total crashes, and a 3.3 percent reduction in KSI crashes. While it is tempting to interpret these findings as indicating that these environments reduce crash risk for older motorists, this study does not identify the routes taken by older adults. The reductions observed in total and KSI crashes may simply reflect the fact that older adults are less likely to travel to these environments. Nonetheless, these reductions in crash incidence are consistent with what has been observed for the population as a whole, where such uses were associated with a 2 percent reduction in total crashes, and a 3 percent reduction in injurious crashes (Dumbaugh and Rae 2009). This suggests that these uses may be leading to meaningful crash reductions, even after accounting for differences in exposure. In either case, future research is needed to account for background levels of exposure.

Of the three land use variables, only big box stores proved to be significantly related to crashes involving older pedestrians and cyclists, with each big box store being associated with an 8.6 percent increase in total and KSI crashes. We suspect that these crashes are attributable to two factors. The first is that, because they are typically located at arterials, big box stores exacerbate the preexisting hazards pedestrians face with traffic along arterials, discussed above. The second is that big box stores typically have large parking lots that pedestrians and motorists alike must walk across to access the store, creating further opportunities for vehicle–pedestrian collisions. Future research is needed to ascertain the extent to which these crashes are attributable to community design or parking lot design.

Pedestrian-scaled retail uses were found to have no effect on the incidence of crashes involving older pedestrians, either positive or negative. Nonetheless, given that such uses are associated with higher levels of utilitarian walking and cycling, and thus significantly higher levels of crash exposure, the failure of this variable to be associated with meaningful increases in pedestrian and cyclist crashes suggests that such uses may be an effective means for providing older adults with safe alternatives to driving. Combined with the finding that such uses may also enhance the safety of older motorists suggests that such environments may be a key means for ensuring safe mobility for older adults. Nevertheless, this too is an area where future research is needed.

Conclusion

This study finds that many of the elements of conventional community design practice, such as arterial thoroughfares, strip commercial uses, and big box stores, are major risk factors for older adults, while networks of lower-speed streets and the design of pedestrian-scaled retail uses appear to be promising strategies for ensuring safe mobility for older adults. It is nonetheless important to acknowledge that this study simply presents associations emerging from a cross-sectional analysis of urban form and crash incidence. Correlation is not causation, and there may be moderating factors that may better explain the relationships presented in this paper. Nonetheless, we hope that the results presented in this study will provide practitioners with information they can use to design communities in a manner that can better address the safety and mobility needs of older adults and that it will encourage future researchers to give greater consideration to this important and under-examined topic.

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Notes

1. According to the Manual for Uniform Traffic Control Devices (FHWA 2003), the safety warrant for a four-way stop is a minimum of five crashes during a twelve-month period. The crashes cited include angle crashes and right and left turn-related crashes (§ 2B.07). Pedestrian or cyclist crashes are not specifically identified as being intersection related, nor is crash severity considered.

2. A protected-only left turn phase only allows drivers to turn left during the green arrow phase of the signal cycle, when the opposing direction of travel is stopped. The objective is to eliminate the crashes that may occur when drivers misjudge gaps in oncoming traffic when attempting a left turn.

References


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