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Community Design and the Incidence of Crashes Involving Pedestrians and Motorists Aged 75 and Older

Final Report

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16. Abstract

Contemporary community design practice has focused on strategies intended to make communities safe for families with children. Comparatively little attention has been given to its effects on older adults. This study employs a series of negative binomial regression models to understand how urban form may affect the incidence of total and killed-or-severely-injured (KSI) crashes involving older drivers and pedestrians. Intersections, strip commercial uses, big-box stores, and arterial thoroughfares pose crash hazards for older motorists, while big-box stores and arterials are problematic for older pedestrians. A network of lower-speed streets was found to be associated with reductions in crashes involving older motorists and pedestrians.

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Executive Summary

By 2050, fully one out of every five persons in the United States—nearly 90 million people—will be over the age of 65. Of these, fully 55 percent will be aged 75 or older (U.S. Administration on Aging, 2009). Despite the widespread recognition of these trends, there has been little examination of the relationship between the built environment and the incidence of crashes involving older adults. This study seeks to fill this void in the literature by examining how measures of the built environment relate to total and killed-or-severely-injured (KSI) crashes involving pedestrians and motorists aged 75 and older.

Negative binomial regressions were used to model crash incidence. For older motorists, arterial thoroughfares, strip commercial uses, and big-box stores—the common features of contemporary suburban design—were associated with significant increases in total and KSI crashes. Pedestrian-scaled retail uses, which are associated with lower operating speeds, were associated with significantly fewer of these crashes.

For older pedestrians, arterial thoroughfares and big-box stores were crash risk factors. The presence of a network of lower-speed streets was associated significantly with fewer crashes involving older pedestrians and motorists alike. This latter finding is particularly significant since much of contemporary community design practice is focused on channeling all local traffic onto arterial thoroughfares, a practice that is likely to exacerbate crash risk for older adults.

1. Introduction

By 2050, fully one out of every five persons in the United States—nearly 90 million people—will be over the age of 65. Of these, fully 55 percent will be aged 75 or older (U.S. Administration on Aging, 2009). Despite the widespread recognition of these trends, there has been little examination of the relationship between the built environment and the incidence of crashes involving older adults. To the extent that the safety of older motorists is considered at all, it is typically through examinations into national fatal crash trends, which report that adults aged 75 or older are more likely to be killed in a traffic crash than other age cohorts. These statistics, combined with the fact that aging is associated with declines in visual acuity and reaction times (Dewar, 2002; Owsley, 2004), are used to support policies intended to eliminate older adults from the driving population. To date, more than half of all states have adopted policies aimed at removing older adults from the driving population, such as more frequent driver's license tests, mandatory vision testing during the licensing process, mandatory in-person license renewals for older adults, and mandatory road tests (U.S. Government Accountability Office, 2007).

Yet before one concludes that older drivers are more dangerous than other age cohorts, several factors warrant consideration. Older bodies are more fragile than younger ones, making older adults more likely to be injured or killed when a crash occurs (Hauer, 1988; Hakamies-Blomqvist, 2004). Older drivers are no more likely than younger drivers to injure or kill other road users on a per-mile-traveled basis (Dulisse, 1997; Maycock, 1997) and are actually *less* likely to injure or kill a pedestrian (Hakamies-Blomqvist, 2004). The current reliance on fatal crash statistics to evaluate the safety of specific sub-populations results in a *frailty bias* against older motorists. Older adults are overrepresented in fatal crash statistics not because they are more hazardous or more crash prone than other age groups, but instead because they are more likely to be killed when a crash occurs—and thus to have their crashes recorded in annual fatal crash statistics.

Rather than being disproportionately prone to crashes, older adults generally drive more cautiously than younger age groups. They are much less likely to be involved in crashes associated with irresponsible or reckless driving, such as single-vehicle, run-off-roadway crashes, crashes involving excessive speeds, or crashes involving a driver following too closely to another vehicle (Hakamies-Blomqvist, 2004; Federal Highway Administration, 1993; Stamatiadis et al., 1991). Such findings are consistent with what is known about the driving patterns of older adults. Older adults compensate for declining abilities by driving more carefully, at lower speeds, and during less hazardous times of day.

Despite being more cautious, older drivers are nevertheless more likely to be killed in a traffic crash than younger drivers, a problem that is expected to increase dramatically with the aging of the baby boom generation. Based on current projections of licensure and annual miles traveled, one author estimated that by 2030, more than 24,000 persons aged 65 and older will be killed annually in traffic crashes—fully three times the number of older adults killed in 2000 (Hakamies-Blomqvist, 2004).

2. Considering the Basis of Contemporary Community Design

The flood of automobile traffic into American cities during the early 20th 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 6,000 persons (see Figure 1). The safety of children would be addressed by reconfiguring communities to prevent the intrusion of traffic onto residential areas. This was to be accomplished by redesigning the street network into a functional hierarchy. Large, traffic-carrying streets (the progenitor of 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 local streets would be designed 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 the major roadways bounding the neighborhood unit (Perry, 1939).

Yet 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 the town of Radburn (see Figure 2), which eliminated residential cut-through traffic entirely through the use of residential cul-de-sacs. While Radburn was a commercial failure (Stein, 1957), the design concepts it embodied were codified by the Federal Housing Administration (FHA) (1936) into design guidance, which was in turn used to identify projects eligible for FHA mortgage insurance. These ideas were further embedded into the subdivision controls that were being adopted by municipalities, thereby embedding these design ideas into 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).

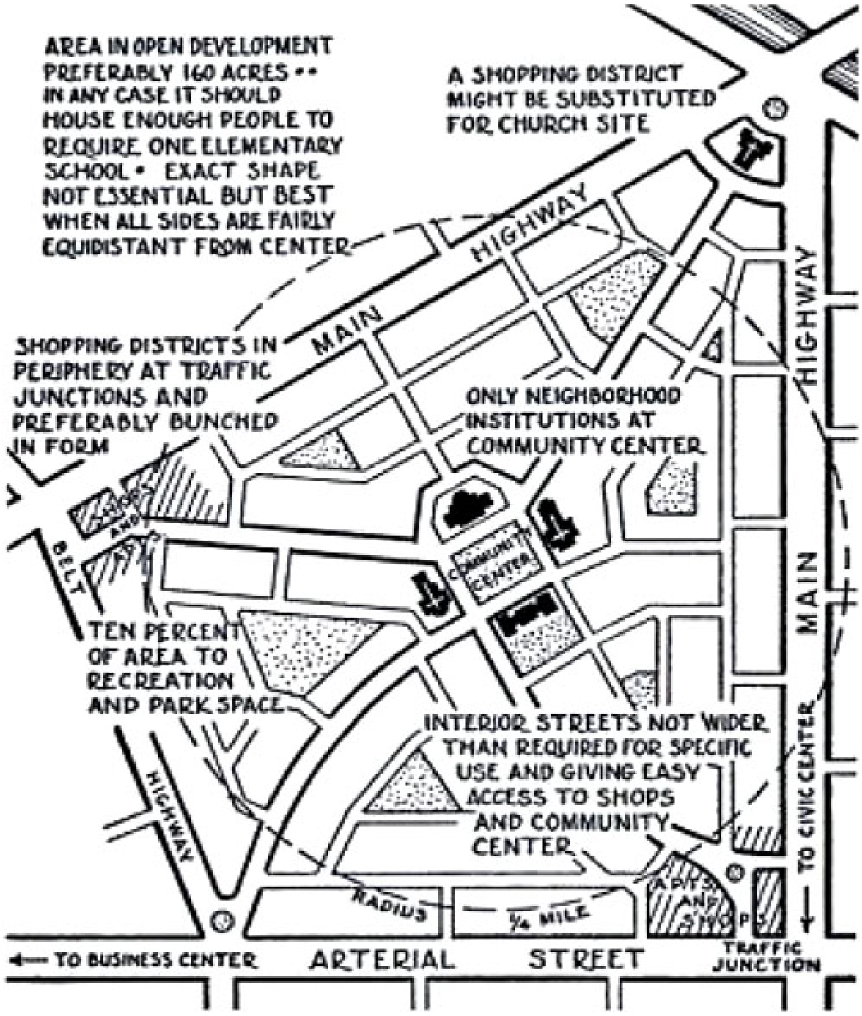


Figure 1: Clarence Perry's Neighborhood Unit (Perry, 1939)

Despite the widespread adoption of the disconnected residential subdivisions, there has been surprisingly little examination of their effects on crash incidence and none that has explicitly examined their 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—i.e., disconnected residential subdivisions—reported fewer crashes than older "grid iron" neighborhoods. In 1995, Eran Ben-Joseph followed up on Marks' 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 that they only examined the crash incidence on local streets and did not account for the possibility that, by relocating traffic and retail uses to arterial thoroughfares, they may simply be shifting crashes from within a community to the arterials that bound it.

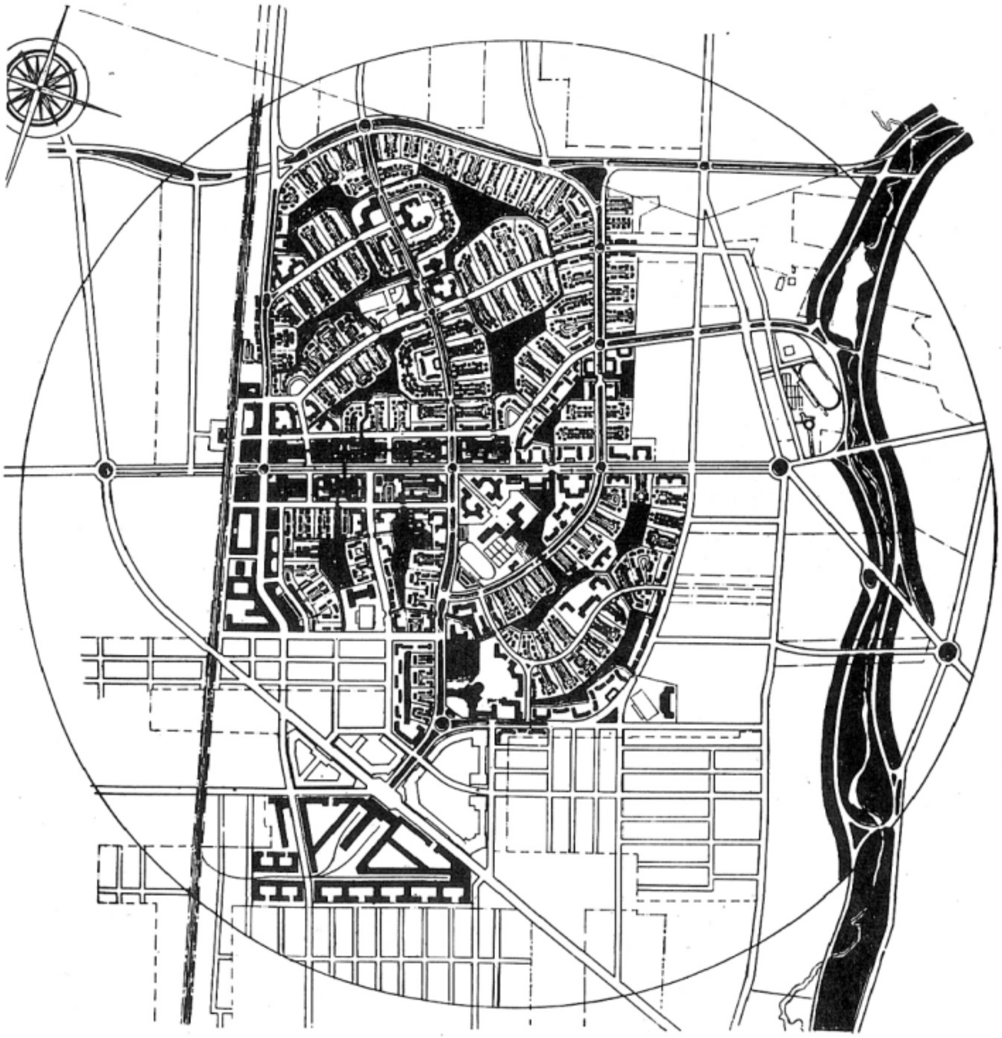


Fig. 28—Plan for the complete town.

Figure 2: Radburn (Stein, 1957)

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) found that these findings held true for crashes involving pedestrians and motorists alike.

3. Variable Definitions and Database Assembly

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 five years (2003-2007) of crash data supplied by the Texas Department of Transportation (TxDOT) and integrated the data into a geographic information system (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 allowed us to examine the spatial distribution of crashes in conjunction with both traffic volumes and the characteristics of 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 most straightforward means of doing so proved to be simply following the region's highway infrastructure. Thus, the study area for this analysis ultimately consisted of the 938 block groups contained within the State Highway 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.

Data Sources

Data were collected and catalogued from multiple agencies, including information on crash incidence, roadway and road network characteristics, traffic volumes, land use characteristics, and demographic characteristics. These data sources, their provider, and the form in which they were provided are detailed in the following subsections.

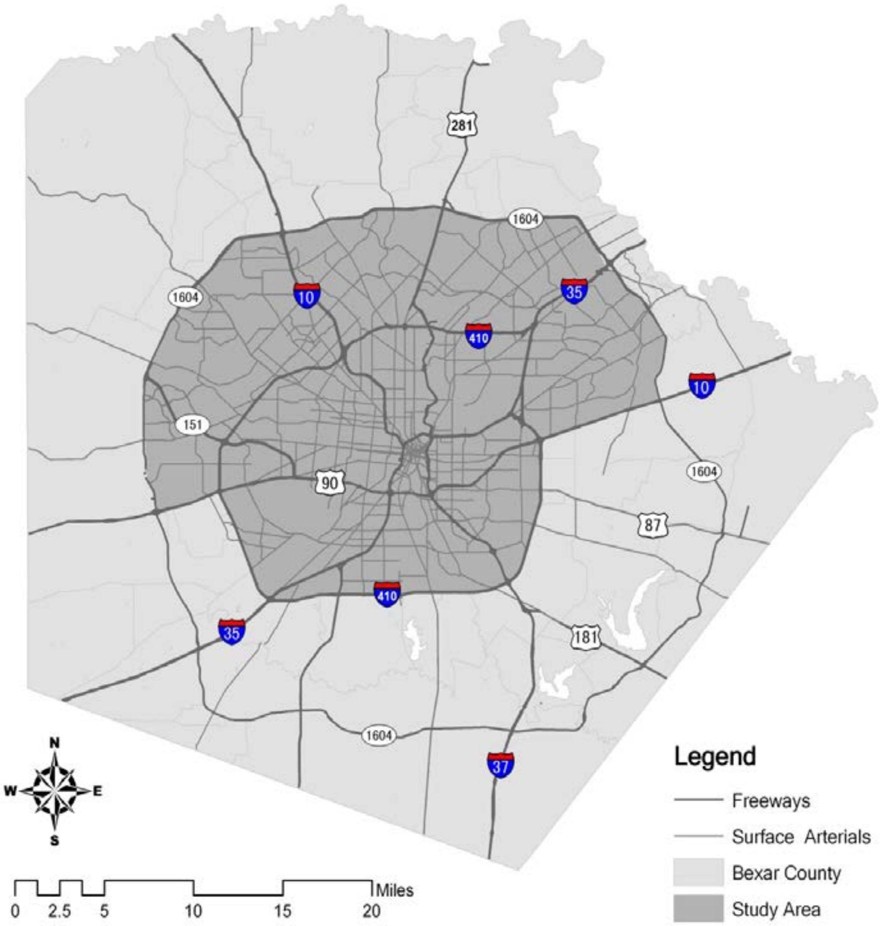


Figure 3: San Antonio-Bexar County Study Area

Dependent Variables: Crash Data (Point Form Data)

Geo-located crash data were provided by the Texas Department of Transportation. Because the crashes included the latitude and longitude coordinates for each crash, we were able to readily incorporate them into the GIS. Using these data, we sought to identify the factors associated with the incidence of 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 75 or older that was involved in a crash. The 75 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). Consequently, 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.

Table 1 shows the crashes involving older adults in the San Antonio study area. Between 2003 and 2007, there were 26,751 crashes involving adults aged 75 and older, of which nearly 3,600, or 13 percent, resulted in their injury or death. 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 the total crashes that occurred, pedestrians and cyclists accounted for more than 5 percent of the total injuries and nearly 30 percent of the total fatalities. Given the low numbers of cyclist and fatal crashes, we combined them with pedestrian and injurious crashes, respectively. For thus study, the dependent variables are total and killed-or-seriously-injured (KSI) crashes involving older drivers and older non-motorists.

Table 1: Crashes Involving Older Adults, 2003-2007

	Total	**KSI**	*Injured*	*Killed*
Driver	**26,533**	**3,361**	*3,308*	*53*
Non-motorized	**218**	**215**	*193*	*22*
Pedestrian	*202*	*199*	*179*	*20*
Cyclist	*16*	*16*	*14*	*2*
Total	**26,751**	**3,576**	*3,501*	*75*

Street and Street Network Data (Line Form Data)

U.S. metropolitan regions develop GIS layers of major roadways for use in federally required regional transportation planning applications. Most, if not all, also supplement this with more comprehensive street network files to assist in planning and programming of local transportation improvements. Correspondingly, we were able to acquire information on the regional road network directly from the San Antonio-Bexar County Metropolitan Planning Organization. The roadway shapefile was provided in line form and included information on the location and mileage of all roadways in the metropolitan region, as well as their functional class (i.e., freeway, principal arterial, minor arterial, collector, local, freeway access lane, and freeway ramp). Note that there are two ways of quantifying roadway mileage: either by the total lane mileage, which is measured as the number of miles of a roadway multiplied by the number of lanes; or by the centerline mileage, which is simply the total miles of a facility, regardless of the number of lanes. Because the San Antonio data did not provide information on the number of lanes, we developed measures of the centerline mileage for each roadway class.

Another valuable source of information is the geometric characteristics of the roadways themselves, i.e., right-of-way width, the number of lanes, the presence or absence of curbing, and the widths of shoulders and medians, among others. Such information, when available, is typically also included in line form, dividing roadways up into road segments based on their design characteristics. Nonetheless, while many state departments of transportation compile these data for state highways, these data were unfortunately not available in a useable form for San Antonio. Some local jurisdictions may likewise have these data for roadways that are not located on the state highway system, although the availability and quality of such data are likely to vary across individual jurisdictions.

Intersections and Street Networks

Because the location and configuration of an intersection may affect crash incidence, we developed operational definitions of different intersections using the previously described road file. We used the connectivity function in ArcMap to define intersection locations from the road network shapefile. False intersections (pseudo-nodes) were eliminated from the data set by identifying only nodes associated with three or more links (see Figure 4). Because earlier research has found that three-leg intersections report substantially fewer crashes than four-leg intersections (Marks, 1957), we proceeded to distinguish between these intersection types in our data. Each intersection was then defined as being three leg (a T intersection), four leg, or five-or-more leg (see Figure 4).

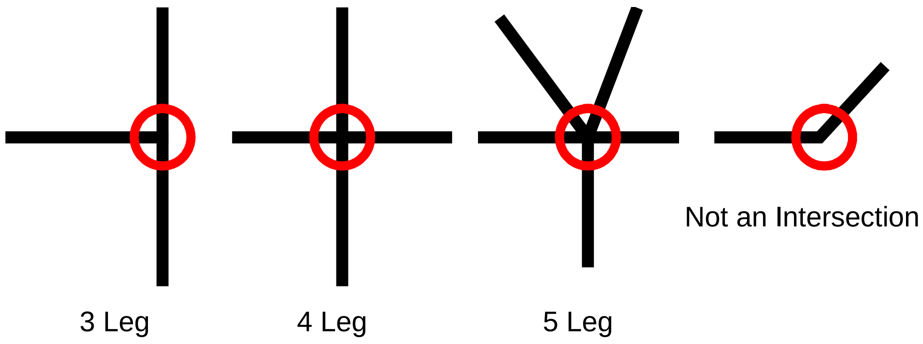


Figure 4: Operational Definition of an Intersection

Parcel-Level Land Use Data (Polygon Form)

Because local taxes are assessed on property values, tax appraisal districts typically maintain a parcel-level database of individual properties within their jurisdiction. In the case of the San Antonio region, this information was collected by the San Antonio-Bexar County appraisal district and included information on the boundaries, sizes, and values of parcels throughout the region, as well as the gross and rentable square footage of non-residential buildings located on the parcel. It also provided rough classifications of each parcel's land use, with parcels being designated as single-family residences, multi-family residences, rental apartments, commercial and retail uses, industrial uses, vacant properties, and tax-exempt properties (e.g., governmental buildings, parks, and churches), among others. The square footage of commercial and retail uses and commercial apartments was likewise provided. These data were provided in polygon form.

The parcel-level data were then used to develop urban form indicators that would permit a more thorough examination of the role of urban design on urban form and crash incidence. Dumbaugh (2006) found that roadways in more urbanized environments, characterized by street-oriented buildings and pedestrian-oriented roadside features, reported fewer crashes, injuries, and deaths than roadways with more suburban characteristics. Conversely, arterial roadways with more suburban characteristics, such as arterial-oriented commercial uses and large parking lots, were found to report higher levels of crash incidence. To account for the effects that different developmental forms might have, we the measures detailed below.

Traffic Volumes (Point and Line Form)

While traffic volumes are often a significant predictor of crash incidence, assembling these data proved methodologically complex. The Texas Department of Transportation provided average daily traffic (ADT) volumes in linear form for all state highways (freeways and principal arterials) in the metropolitan area. The City of San Antonio supplemented this information with traffic counts at 804 locations off the state system. These streets consist of all principal arterials, minor arterials, and collector roadways in the region. Traffic volumes for select local roadways were also provided, but because of the limited number of roadways for which local ADT was available (roughly 10 percent of all local road mileage in the city), we omitted this information from our calculation of vehicle miles traveled (VMT). Consequently, our data present ADT for freeways, arterials, and collectors.

A second issue is related to the integration of the state and city ADT information. Unlike the state data, the city's ADT data were provided in point form. To make these data compatible, we converted the San Antonio point data into a linear form and extrapolated the corresponding point value for the length of the roadway (see Figure 5). Where multiple ADT values were present on a given roadway, the extrapolated values were extended outward toward the midpoint between them. This procedure allowed us to merge the ADT information from both TxDOT and the City of San Antonio into a single, master ADT shapefile.

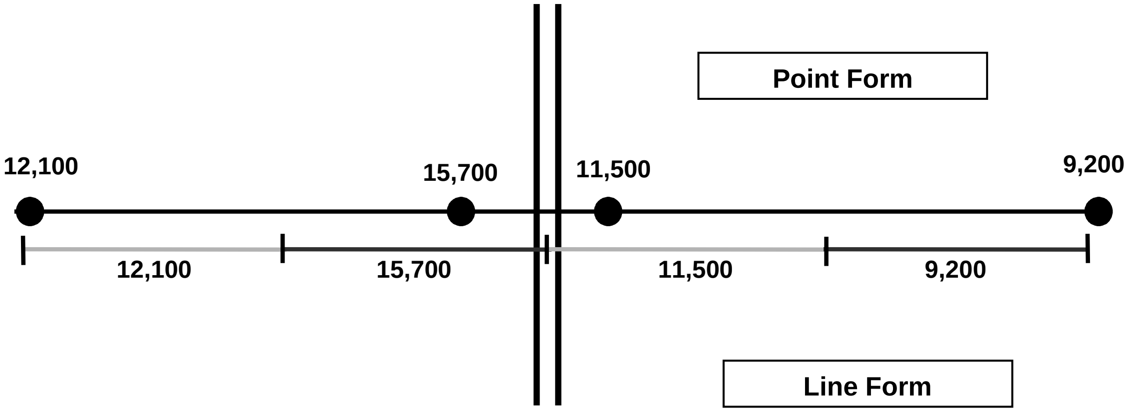


Figure 5: Converting ADT from Point Form to Line Form

Demographic Information (Polygon Form)

To account for the effect that population characteristics may have on crash incidence, we sought to further obtain information on the demographic characteristics of the local population. Demographic information is collected as part of the U.S. Census, and more recent data may be available from the metropolitan planning organization at the level of the traffic analysis zone. Because larger geographic units mask internal community design variation, we used census block groups, which provide accurate population information but are nevertheless small enough to be relatively homogeneous in their design characteristics. Information available at the block group level includes total population of the block group; the number of persons by race, age, and sex; and information on median incomes and median home values.

Neighborhood-Level Database Assembly

While the definition of a neighborhood seems obvious at a nominal level, defining neighborhoods in an operational form proved methodologically complex. Each jurisdiction is likely to classify neighborhoods in a locally unique manner, and there is no single right means for doing so. Because we sought reliable information on the demographic characteristics of a geographic area, we relied on block group definitions from the U.S. Census to determine neighborhood boundaries. While such an approach best suited the larger research objectives of this effort, other neighborhood definitions are available, such as defining neighborhoods based on the jurisdictional boundaries of neighborhood or homeowners associations.

Regardless of how neighborhood boundaries are operationalized, two additional issues that emerge are the methods for addressing micro-level spatial variation associated with the use of different GIS layers, as well as the related problem of how to meaningfully assign information occurring along a neighborhood's boundaries. Previous researchers developing crash forecasting models have sought to avoid these attribution problems by eliminating information occurring on the boundaries of their units of analysis (Ladron et al., 2004). The problem with this approach, however, is that both traffic analysis zones and census geography typically use arterial thoroughfares as geographic boundaries. Since arterial roadways often carry an overwhelming share of the traffic generated by a community and are thus likely to experience a large share of the crashes occurring in a community, the effective result of eliminating boundary information is that neighborhood crash incidence is likely to be severely underestimated.

To resolve this problem, we defined neighborhoods as being comprised of the block group itself, plus the streets along its edges. To capture the relevant information, we developed 200-foot buffers around each block group (roughly the right-of-way width of a fully designed principal arterial), and assigned the roadway and crash information occurring within the buffer area to the block group it adjoined (see Figure 6). This approach thus regards streets located on the edges of neighborhoods as being part of the neighborhood itself, an approach that roughly corresponds with the way individuals define the boundaries of their neighborhood. While such an approach does result 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 neighborhood, 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 is not lost due to the means by which the unit of analysis was operationalized.

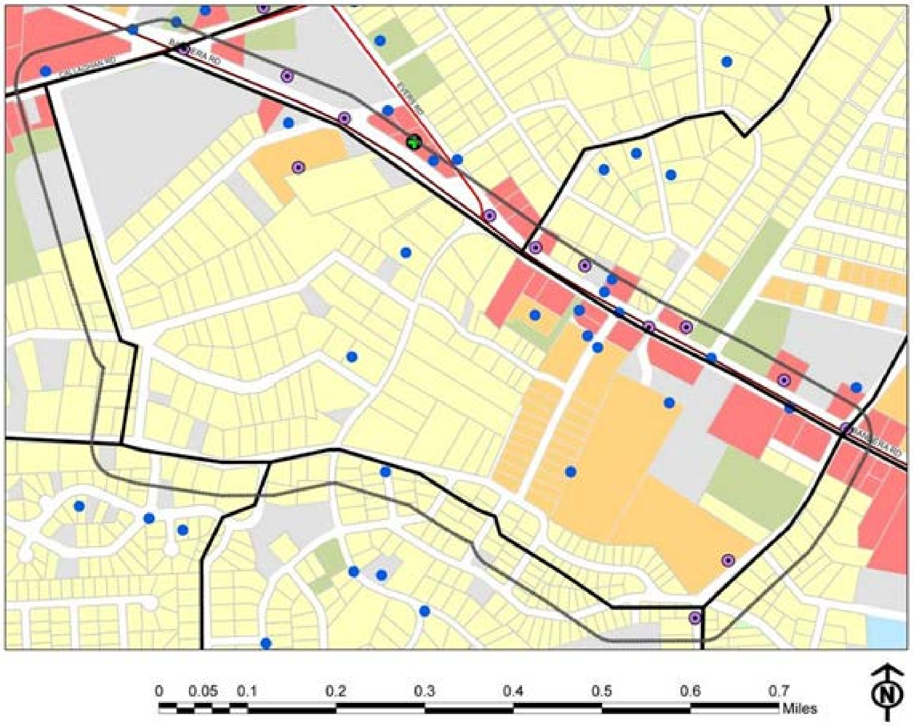


Figure 6: Illustrative Census Block Group and Buffer

Nevertheless, two remaining operational problems remain unresolved. The first is the modifiable area unit problem (MAUP), which relates to the effects that different geographic aggregations may have on the observed values for a variable of interest (Openshaw and Taylor, 1979). Because values for a specific variable, such as population or median income, will vary based on the manner in which an area is bounded, the specific values observed are not truly random but are instead a product of the means by which a geographic area is defined. A second and related problem is the issue of spatial autocorrelation, which relates to the independence of our observations. Because the characteristics of a geographically defined area are likely to be similar to, and perhaps influenced by, the characteristics of adjacent areas, the specific observations cannot be said to be truly independent. Such issues have not been examined in the context of traffic safety analysis and are an important area for future research.

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 that 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.

- VMT (in millions). Because heavier traffic volumes can create more opportunities for crashes to occur, we sought to control for the effects of VMT on crash incidence. The Texas Department of Transportation provided us with ADT volumes for all 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 1 million. The resulting value is the block-group-level VMT in millions.
- Population aged 75 and older. Because the number of older adults in a block group may influence local crash incidence, we included the number of persons aged 75 and older as a control variable.
- Intersection counts. Intersections create locations where opposing streams of traffic cross, and are thus locations where conflicts between roadway users may emerge. Previous research has found that a substantial portion of the crashes involving older adults tend to occur at intersections, particularly when older adults attempt to turn left across multiple lanes of traffic (Hauer, 1988; Kloeppel et al., 1995; Partyka, 1983; Preusser et al., 1998). This variable is the count of the number 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 the 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 uses 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 well, 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 comprised of 50,000 square feet or more and having a FAR of 0.4 or less (i.e., more surface parking than building area). This variable is the sum of these uses 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 et al., 2009) and reduced crash incidence (Dumbaugh and Rae, 2009). Nonetheless, there has been little examination of how such uses may influence the safety of older adults. To determine whether such uses may be beneficial, the count of such uses was included as an independent variable in the models. Pedestrian-scaled retail uses are defined as a commercial or retail use of 20,000 square feet or less but developed at a FAR 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 uses in a neighborhood and serves as a rough indicator of a neighborhood's urbanism (see Figure 7).

Figure 7: Pedestrian-Scaled Retail Uses in San Antonio

- Miles of arterials. Conventional community design practice seeks to channel all non-residential traffic onto arterial thoroughfares, which are intended to accommodate higher-speed automobile traffic in a safe and efficient manner. Age-related declines in 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 MPH or less, but they have increasing difficulty doing so when vehicles are traveling at higher speeds (Chandraratna, et al, 2002; Scialfa et al., 1991; Staplin, 1995). Consequently, 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. Consequently, 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 an 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 MPH and 35 MPH, speeds that are not only compatible with the driving abilities of older adults but that 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 8).

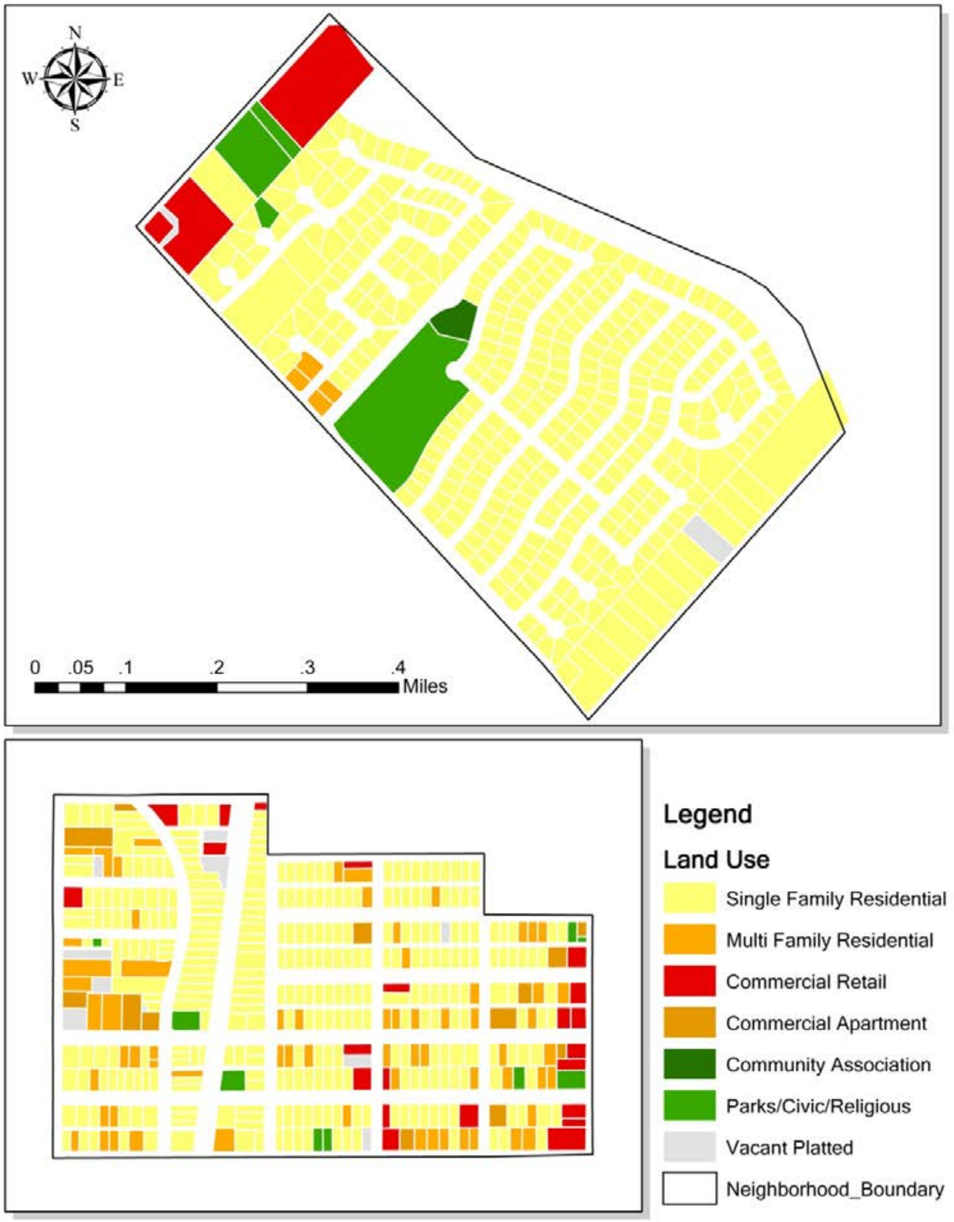


Figure 8: Street Network Density: The Suburban Block Group (Top) Has a Street Density of 2.58, While the Urban Block (Bottom) Has a Street Density of 3.90.

4. Examining Crashes Involving Older Pedestrians

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 this analysis. Negative binomial regression models have been widely applied in the recent traffic safety literature and are regarded as the preferred statistical model for analyzing crash frequency and severity (Ladron et al., 2004). While crash data can be converted to a more normally distributed form by dividing crashes by either the number of persons or vehicle miles traveled and using the natural log of the corresponding value, this approach is discouraged since it forces crashes to be understood principally as a factor of the denominator of the measure, an unwarranted methodological assumption (Hauer, 1997). Negative binomial models allow crash frequency to be measured directly, and the inclusion of block group acreage, population density, and vehicle miles traveled as independent variables in the models accounts for whatever influence these factors might have on differences in crash incidence.

A second issue is the identification of the appropriate test statistics. In the conventional application of regression models, null hypothesis testing is used, and only coefficients and test statistics for variables entering at statistically significant levels are reported. This approach has received a good deal of criticism in the recent traffic safety literature since it presumes that if we cannot be statistically confident in our results at some arbitrary level (typically the 0.05, or 95 percent, level), then we should regard our results as empirically meaningless. As Hauer (2004) has shown, using statistical methods in this manner has led to the adoption of policies that have proven detrimental to safety since it encourages researchers to ignore meaningful associations that exist in their data.[1] To address this issue, we report the coefficients and test statistics for all modeled variables, and include 95th percentile confidence intervals. While significance levels and test coefficients are included for their usefulness in discussing the model results, the range of crash variation specified by 95th percentile confidence intervals should be regarded as the best possible estimate of a variable's actual safety effects.

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 vehicle miles travelled (MVMT) and the number of persons aged 75 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 percent and 1.9 percent increase in total and KSI crashes, respectively, while each big-box store was associated with a 7.2 percent and 3.9 percent increase in these crash types, respectively. 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 to 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.

Table 2: Total Crashes Involving Older Drivers

	Coef.	z	p	95% Conf. Interval	
Constant	2.5903	26.540	0.000	2.3990	2.7816
Block group acreage	−0.0009	−6.900	0.000	−0.0011	−0.0006
MVMT	0.0025	9.040	0.000	0.0019	0.0030
Population 75 and older	0.0033	7.180	0.000	0.0024	0.0041
No. of intersections	0.0044	3.990	0.000	0.0023	0.0066
No. of strip commercial uses	0.0254	9.010	0.000	0.0198	0.0309
No. of big-box stores	0.0716	3.860	0.000	0.0352	0.1080
No. of pedestrian-scaled retail uses	−0.0292	−3.720	0.000	−0.0445	−0.0138
Miles of surface arterials	0.0902	3.100	0.002	0.0332	0.1473
Density of lower-speed streets	−0.1165	−5.610	0.000	−0.1573	−0.0758
n = 938					
Log likelihood = −3744					
Chi2 = 684 (0.000)					

Table 3: KSI Crashes Involving Older Drivers

	Coef.	z	p	95% Conf. Interval	
Constant	0.9155	8.230	0.000	0.6976	1.1334
Block group acreage	−0.0007	−4.530	0.000	−0.0010	−0.0004
MVMT	0.0022	7.200	0.000	0.0016	0.0027
Population 75 and older	0.0020	4.770	0.000	0.0012	0.0028
No. of intersections	0.0023	1.650	0.098	−0.0004	0.0050
No. of strip commercial uses	0.0199	6.820	0.000	0.0142	0.0257
No. of big-box stores	0.0387	2.150	0.031	0.0035	0.0739
No. of pedestrian-scaled retail uses	−0.0327	−3.900	0.000	−0.0491	−0.0163
Miles of surface arterials	0.0965	3.250	0.001	0.0383	0.1546
Density of lower-speed streets	−0.1366	−5.240	0.000	−0.1877	−0.0856
n = 938					
Log likelihood = −2024					
Chi2 = 446 (0.000)					

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.

Table 4: Crashes Involving Older Pedestrians and Cyclists

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

n = 938

Log likelihood = −520

Chi2 = 69 (0.000)

Table 5: KSI Crashes Involving Older Pedestrians and Cyclists

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

n = 938

Log likelihood = −515

Chi2 = 71 (0.000)

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.

5. Discussion: Implications for Community Design Practice

Considered as a whole, the results of this study suggest that conventional community design practice, which is directed at redirecting automobile traffic away from residential areas and onto arterials, may be problematic for older adults. The findings of this study suggest that 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 in the following sections.

Network Configuration

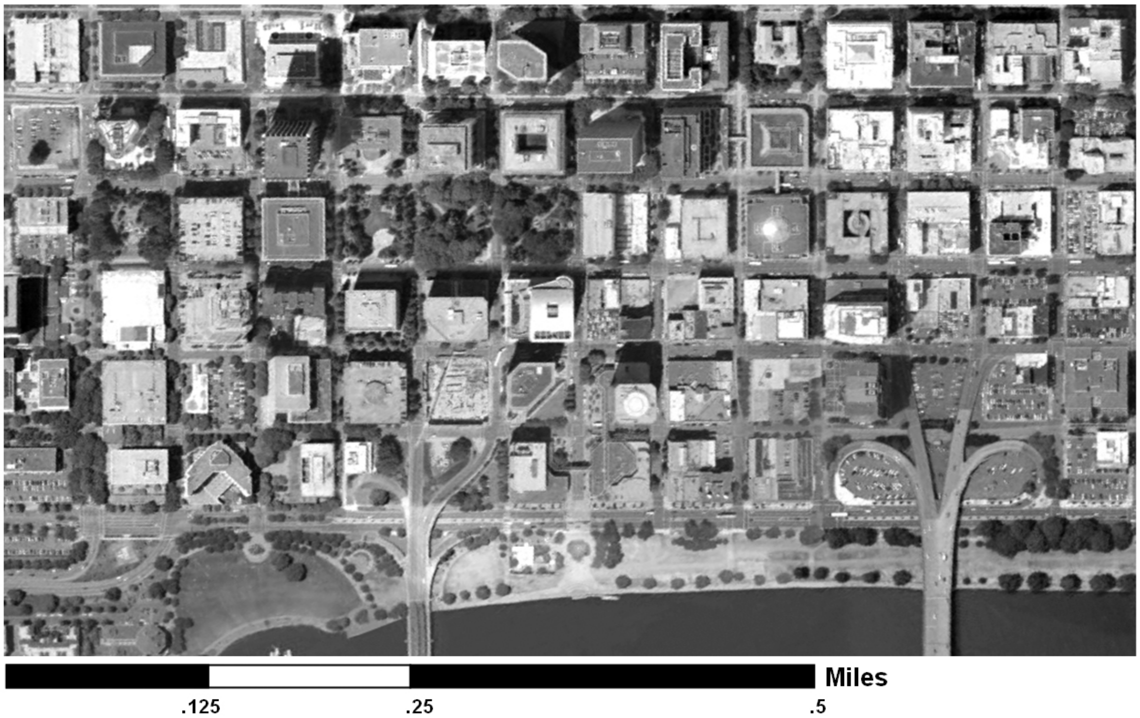
Whether they are traveling as drivers or pedestrians, older adults have a difficult time negotiating through traffic traveling at high speeds. The hierarchical street networks and single-use characteristics of conventional community design practice channel all non-residential traffic onto arterial thoroughfares, 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 involve a serious injury or death.

Rather than addressing the inherent safety problems such environments create for older adults, the conventional approach to addressing this problem is to presume that such problems are largely attributable to the decline in driving abilities associated with aging. Nonetheless, 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 (AARP), older drivers often forego driving at night, during congested time periods, and, when possible, along higher-speed roadways. Nonetheless, the 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 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 were also found to result 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 enhancing 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 et al., 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 drivers. Yet the magnitude of the effect was small, with each intersection associated with a 0.4 percent and 0.2 percent increase in total and KSI crashes, respectively. One would need to add at least 29 intersections per mile to negate the crash reduction benefits associated with adding a single mile of lower-speed route, and 59 intersections to offset the reduction in crashes involving a death or serious injury. Even Portland, Oregon, with its 200-foot block spacing, is only able to squeeze in about 20 intersections per linear mile of roadway (see Figure 9), meaning that even in an extremely dense grid of streets, the benefits of having a network of lower-speed streets greatly outweighs any disadvantages associated with more frequent intersections.



(Image source: Google Earth)

Figure 9: Fewer than 20 Intersections per Mile in Downtown Portland, Oregon

The configuration of lower-speed networks may further reduce the incidence of intersection-related crashes for older adults as well 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 et al., 2002; Matthias et al., 1996; Staplin, 1995; Yi, 1996) and 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. Yet future research is needed to fully bear this assertion out.

While intersections remain a problem for older adults, even this problem 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.[2] Collectively, this results 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 et al., 2002; Hallmark and Mueller, 2004; Matthias et al., 1996; Staplin et al., 1998; Ulfarsson et al., 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. Yet, the problem is likely 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, a fact evidenced by the profoundly negative effects that arterials had on crash incidence. Given that older adults are less likely than younger cohorts to cross the street at non-intersection 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. Despite the fact that the intersection variable did prove to be significantly related to increased crash incidence, we encourage readers to refer to the 95 percent confidence interval of the estimates when evaluating the hazards associated with intersections, which indicates that intersections are generally hazardous locations for cyclists and pedestrians.

Location and Configuration of Retail and Commercial Uses

Like intersections, the 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 use is associated with a 2.5 percent increase in total crashes and 1.9 percent increase in KSI crashes involving older drivers. Each big-box store is associated with a 7.1 percent increase in total crashes and a 3.9 percent increase in KSI crashes. Stating these statistics another way, each strip commercial use posed between 6 and 8 times the crash risk to older adults as did 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 proved problematic for older drivers, this did not prove 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 meaning that these environments reduce crash risk for older motorists, this study does not identify the routes taken by older adults, meaning that 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), which suggests that 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 previously. 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, however.

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, this 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. Yet it is important to observe that this study simply presents associations emerging from a cross-sectional analysis of urban form and crash incidence. Correlation is not causation, and moderating factors may exist that better explain the relationships presented in this report. Nonetheless, we hope that the results presented in this study will provide practitioners with information they can use to innovate community design 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 underexamined topic.

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Notes

[1] An example of this is the research used to justify the adoption of permitted right-turn-on-red policies during the 1970s and 1980s. Despite every study on the subject reporting that crashes involving pedestrians increased following the adoption of permitted right turns on red, the limited number of observations in each individual study failed to identify the relationship as being statistically significant. Consequently, researchers and policy makers concluded that right turns on red did not increase the hazards to pedestrians, despite the obviously higher absolute number of pedestrian crashes evidenced in their data. In a re-examination of this subject, Hauer aggregated the results of these studies together, thereby increasing the total number of observations and found that when considered as a whole, such practices did, in fact, result in a significant increase in crashes involving pedestrians (Hauer, 2004).

[2] According to the *Manual on Uniform Traffic Control Devices* (Federal Highway Administration, 2003), the safety warrant for a four-way stop is a minimum of five crashes during a 12-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.

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