Safe Streets, Livable Streets

Eric Dumbaugh

Transportation safety is a highly contentious issue in the design of cities and communities. While urban designers, architects, and planners often encourage the use of aesthetic streetscape treatments to enhance the livability of urban streets, conventional transportation safety practice regards roadside features such as street trees as fixed-object hazards and strongly discourages their use. In this study, I examine the subject of livable streetscape treatments and find compelling evidence that suggests they may actually enhance the safety of urban roadways. Concerns about their safety effects do not appear to be founded on empirical observations of crash performance, but instead on a design philosophy that discounts the important relationship between driver behavior and safety. This study traces the origin and evolution of this philosophy, and proposes an alternative that may better account for the dynamic relationships between road design, driver behavior, and transportation safety.

Eric Dumbaugh is a doctoral candidate in the School of Civil and Environmental Engineering at the Georgia Institute of Technology. His research focuses on context-sensitive solutions, nonmotorized travel, and transportation system safety.

Journal of the American Planning Association,
Vol. 71, No. 3, Summer 2005.

> The danger in supplanting the real measure of safety (i.e., crash frequency and severity) by surrogates arises when the link between the two is conjectural, when the link remains unproven for long, and when the use of unproven surrogates becomes so habitual that the need to eventually speak in terms of crashes is forgotten. (Hauer, 1999a, p. 17)

Beyond simply acting as thoroughfares for motor vehicles, urban streets often double as public spaces. Urban streets are places where people walk, shop, meet, and generally engage in the diverse array of social and recreational activities that, for many, are what makes urban living enjoyable. And beyond even these quality-of-life benefits, pedestrian-friendly urban streets have been increasingly linked to a host of highly desirable social outcomes, including economic growth and innovation (Florida, 2002), improvements in air quality (Frank et al., 2000), and increased physical fitness and health (Frank et al., 2003), to name only a few. For these reasons, many groups and individuals encourage the design of "livable" streets, or streets that seek to better integrate the needs of pedestrians and local developmental objectives into a roadway's design.

There has been a great deal of work describing the characteristics of livable streets (see Duany et al., 2000; Ewing, 1996; Jacobs, 1961), and there is general consensus on their characteristics: livable streets, at a minimum, seek to enhance the pedestrian character of the street by providing a continuous sidewalk network and incorporating design features that minimize the negative impacts of motor vehicle use on pedestrians. Of particular importance is the role played by roadside features such as street trees and on-street parking, which serve to buffer the pedestrian realm from potentially hazardous oncoming traffic, and to provide spatial definition to the public right-of-way. Indeed, many livability advocates assert that trees, as much as any other single feature, can play a central role in enhancing a roadway's livability (Duany et al., 2000; Jacobs, 1993).

While most would agree that the inclusion of trees and other streetscape features enhances the aesthetic quality of a roadway, there is substantive disagreement about their safety effects (see Figure 1). Conventional engineering practice encourages the design of roadsides that will allow a vehicle leaving the travelway to safely recover before encountering a potentially hazardous fixed object. When one considers the aggregate statistics on run-off-roadway crashes, there is indeed

cause for concern. In 2003 alone, there were over 8,500 fatalities involving roadside objects such as trees and utility poles on U.S. roadways, accounting for more than 20% of the total fatalities for that year (National Highway Traffic Safety Administration [NHTSA], n. d.). Correspondingly, designing livable streets is often more difficult than simply counterbalancing the needs of motorists with those of pedestrians. How is the transportation designer to conscientiously incorporate design elements that may result in the loss of life?

This study details existing design guidance and literature, as well as the historical evolution of contemporary safety practice, and reports the results of an empirical test of the professional assumptions that guide the current approach to addressing safety through design. It concludes by outlining an approach to urban roadway design that may better address the twin goals of safety and livability.

Considering the Literature on Roadside Safety

The initial motivation behind this research effort was an attempt to understand the safety impacts of livable streetscape treatments on urban roadways. On this issue, the design guidance is clear: "for all types of highway projects,[1] clear zones should be determined or identified and forgiving roadsides established" (American Association of State Highway and Transportation Officials [AASHTO], 1997, p. 14). In practice, this entails providing a clear roadside adjacent to the vehicle travelway, with a preferred width of 30 feet.[2] In terms of how to best accomplish this goal, AASHTO's (2002) *Roadside Design Guide*, the central authority on the design of safe roadsides, is also clear:

> Through decades of experience and research, the application of the forgiving roadside concept has been refined to the point where roadside design is an integral part of transportation design criteria. Design options for reducing roadside obstacles, in order of preference, are as follows:
>
> 1. Remove the obstacle.
> 2. Redesign the obstacle so it can be safely traversed.
> 3. Relocate the obstacle to a point where it is less likely to be struck.
> 4. Reduce impact severity by using an appropriate breakaway device.
> 5. Shield the obstacle with a longitudinal traffic barrier designed for redirection or use a crash cushion.
> 6. Delineate the obstacle if the above alternatives are not appropriate. (pp. 1–2)

Figure 1. Livable streetscape treatments: urban amenities or roadside hazards?

While the *Roadside Design Guide* cites "decades of experience and research," there is very little information on the use of aesthetic streetscape features, and much of the existing literature on the application of clear zone policies in urban environments is problematic, at best. The definitive work on the subject is a study that describes the physical characteristics of trees involved in crashes within the City limits of Huntsville, Alabama (Turner & Mansfield, 1990). This study found that most crashes involving trees occur within 20 feet of the roadway, that 75% of the reported crashes involved trees with a caliper width 12 inches or more, and that almost 60% occurred on a horizontal curve.[3] While such information is useful for understanding the characteristics of tree-related crashes, it does not lead to the conclusion that eliminating trees with any or even all of these characteristics will have any effect on a roadway's safety. Such conclusions can only be made by examining the actual crash performance of eliminating trees in urban areas, as measured by changes in crash frequency and severity.

Indeed, there is a growing body of evidence suggesting that the inclusion of trees and other streetscape features in the roadside environment may actually reduce crashes and injuries on urban roadways. Naderi (2003) examined the safety impacts of aesthetic streetscape enhancements placed along the roadside and medians of five arterial roadways in downtown Toronto. Using a quasi-experimental design, the author found that the inclusion of features such as trees and concrete planters along the roadside resulted in statistically significant reductions in the number of mid-block crashes along all five roadways, with the number of crashes decreasing from between 5 and 20% as a result of the streetscape improvements. While the cause for these reductions is not clear, the author suggests that the presence of a well defined roadside edge may be leading drivers to exercise greater caution.

Ossenbruggen, Pendharkar, and Ivan (2001) examined sites with urban, suburban, and residential characteristics in New Hampshire and hypothesized that the urban "village" areas, with greater traffic volumes and more pedestrian activity, would be associated with higher numbers of crashes and injuries. Instead, they found the opposite: the village areas, which had on-street parking and pedestrian-friendly roadside treatments, were two times less likely to experience a crash event than the comparison sites. The authors associate these crash reductions with the characteristics of the roadside environment, which included sidewalks, mixed land uses, and other "pedestrian-friendly" roadside features. The authors also attributed the safety performance to reduced speeds, noting that "since no speed limit signs are erected at village sites, it suggests [speeds] are self regulating" (p. 496).

A study of two-lane roadways by Ivan, Pasupathy, and Ossenbruggen (1999) found that while shoulder widths were associated with reductions in single-vehicle, fixed-object crashes, they were also associated with a statistically significant *increase* in total crashes, with multiple-vehicle crashes offsetting safety gains achieved through reductions in fixed-object crashes. The authors comment that "the positive coefficient on right shoulder width is troubling; one normally expects a wider shoulder to be a safety feature" (p. 702).

Finally, Lee and Mannering (1999) examined run-off-roadway crashes along a 100-km section of an arterial roadway in Washington State that traveled through both urban and rural environments. Using a negative binomial model, the authors sought to associate crash frequencies with the characteristics of the roadside environment. While their model for rural areas performed as expected, with trees and other features being associated with a statistically significant increase in the number of roadside crashes, their model for urban areas produced radically different results (see Table 1). Not only were trees not associated with crash increases, but the model coefficients entered negatively at a statistically significant level, indicating that the presence of trees in urban areas was associated with a decrease in the probability that a run-off-roadway crash would occur.

The authors attribute these unexpected crash reductions to the fact that there are fewer trees in urban areas than in rural ones, but this begs the question: even if there are fewer trees in urban areas, which suggests that their presence would violate driver expectancy, why are they associated with statistically significant crash reductions?

Other roadside features proved to be statistically related to crash reductions as well. The number of sign supports was associated with crash reductions, as was the presence of miscellaneous fixed objects, a variable that included such roadside features as mailboxes. Further, wider lanes and shoulders were associated with statistically significant *increases* in crash frequencies.

Interestingly, clear zones are not the only design feature for which such safety anomalies appear. Hauer (1999a) reexamined the literature on lane widths and found that there was little evidence to support the assertion that widening lanes beyond 11 feet enhances safety. Instead, the literature has almost uniformly reported that the safety benefit of widening lanes stops once lanes reach a width of roughly 11 feet, with crash frequencies increasing as lanes approach and exceed the more common 12-foot standard.[4] Further, in a series of broad-sweeping and profoundly important studies, Noland (2001, 2003) and Noland and Oh (2004) consistently found that when one controls for intervening factors such as time-series effects, seat belt use,

Variable	Estimated coefficients	*t*-statistic
Constant	−1.983	
Roadway characteristics		
Broad lane indicator (1 if lane is greater than 3.69 meters, 0 otherwise)	1.684	3.984
Median width (meters)	−0.017	−3.781
Roadside characteristics		
Bridge length (meters)	4.610	2.145
Distance from outside shoulder edge to guardrail (meters)	0.113	3.655
Fence length (meters)	5.781	2.870
Number of isolated trees in a section	−0.093	−1.857
Number of miscellaneous fixed objects in a section	−0.094	−2.140
Number of sign supports in a section	−0.080	−3.515
Shoulder length (meters)	−1.042	−1.461
Dispersion parameter	0.661	2.680
Restricted log likelihood	−686.57	
Log likelihood at convergence	−681.53	
Number of observations	1,584	

Table 1. Negative binomial estimation results for crash frequencies in urban areas (Lee & Mannering, 1999; reprinted by permission).

and the demographic characteristics of the population, conventional design "improvements" result in increases in crashes and fatalities.

Indeed, there are a host of safety anomalies in the existing design literature, but as Noland and Oh (2004) stated, the problem is that

> Studies that find unexpected or unconventional results tend to dismiss these results as aberrations and have not examined them in further detail. . . . The results of many of these studies lead us to conclude that the impact of various infrastructure and geometric design elements on safety are inconclusive. Most studies using sophisticated statistical techniques either find no association, or an unexpected association from infrastructure changes assumed to be beneficial. (p. 527)[5]

Thus, a key question emerges: why does contemporary design guidance recommend practices that the best available evidence suggests may have an ambiguous or even negative impact on safety, and paradoxically, to do so under the auspices that they constitute a safety enhancement?

The Passive Safety Paradigm

While safety has been a concern for the transportation design profession throughout its history, the current approach to addressing transportation safety received its philosophical basis as part of the transportation safety movement of the 1960s, a movement that resulted in the National Highway Safety Act, the creation of the National Highway Traffic Safety Administration (NHTSA), the adoption of the *Roadside Design Guide*, crash testing, and the development of air bags, among other features of the contemporary transportation safety landscape. This movement, led by William Haddon and promoted by figures such as Daniel Patrick Moynihan and Ralph Nader, sought to apply the principles of epidemiology to transportation safety issues (Gladwell, 2001; Kratzke, 1995; McLean, 2002; Viano, 2002; Weingroff, 2003).[6]

As a profession, epidemiology is based on the work of John Snow, an English physician who sought to address an outbreak of cholera that plagued London in the 1850s. While current medical theory asserted that the spread of cholera was associated with "vapors," Snow hypothesized that cholera was not airborne, but was instead transmitted through polluted water supplies. Using what was at the time a highly elaborate, data-driven analysis, Snow mapped out the locations of affected households, and determined that these households were indeed sharing a common water source. In an episode that has since become legendary, Snow sought to resolve this problem in one particularly hard-hit neighborhood by implementing a strategy that was both simple and radical: rather than encouraging residents to adopt behavioral modifications, such as boiling infected water or using an alternative water supply, Snow simply removed the handle from the pump of the affected well, thereby neutralizing the environmental cause of the hazard (Rosenberg, 1962).

William Haddon, an epidemiologist trained at the Harvard School of Public Health during the 1950s, likewise believed that it was difficult, if not impossible, to prevent people from engaging in behaviors that lead to traffic injuries and fatalities. Instead, Haddon proposed a *passive* approach: rather than relying on behavioral modifications to prevent crashes from occurring, Haddon believed the design objective should be to enable a "crash without an injury" by physically engineering safety features into vehicles and their environments (Gladwell, 2001). The idea was compelling: what if transportation professionals could

design vehicles and roadways to eliminate the injuries associated with a crash event?

Clear Zones, Highways, and Passive Safety

The life safety implications of the passive approach were not lost on Ralph Nader. In 1965, Nader published *Unsafe At Any Speed*, a critique of the auto industry based on Haddon's passive safety philosophy. Nader's book generated a public outcry to address the "designed-in" dangers of the nation's automobiles and transportation system, leading both congress and AASHO (later AASHTO) to hold special hearings on the subject in 1966. Figures such as Nader and Haddon reported to these committees, but testimony by Kenneth Stonex played perhaps the central role in formulating the contemporary perspective on safe roadway design.

One of the key problems identified by the AASHO committee was the large number of fatalities associated with single-vehicle, run-off-roadway crashes. To address this issue, they heard testimony from Stonex, a General Motors employee responsible for designing the "Proving Ground," an experimental "crashproof" highway that had 100-foot clearances on either side of the travelway (McLean, 2002; Weingroff, 2003). Based on the test performance of the Proving Ground, Stonex was of the opinion that "What we must do is to operate the 90% or more of our surface streets just as we do our freeways . . . [converting] the surface highway and street network to freeway and Proving Ground road and roadside conditions" (Weingroff, 2003, p. 147).

With respect to fixed-object crashes specifically, Stonex reported that most vehicles on the Proving Ground came to a stop within 30 feet after leaving the roadway. Thus, the committee concluded that eliminating fixed objects within 30 feet of the travelway would eliminate most fixed-object crashes and, in a conjectural leap, that the roadway would therefore be safer as a result. The 30-foot clear zone standard (with adjustments for sideslope) was thus incorporated into AASHO's 1967 publication *Highway Design and Operational Practices Related to Highway Safety*, as well as the revised 1974 edition, and remains in the subsequent editions of the *Roadside Design Guide* (AASHTO, 1974, 2002; McLean, 2002; Weingroff, 2003).

Side Effects of the Passive Treatment

Prior to the 1960s, transportation safety had been addressed primarily through strategies aimed at encouraging drivers to engage in safe behavior, an approach that led to the development and codification of the nation's signing practices and motor vehicle laws. Yet, as Nader testified, focusing on behavior was not an adequate solution to the problem:

> Even if people have accidents, even if they make mistakes, even if they are looking out the window, or they are drunk,[7] we should have a second line of defense for these people . . . the sequence of events that leads to an accident injury can be broken by engineering measures even before there is a complete understanding of the causal chain. (quoted in Weingroff, 2003, p. 154)

Following the 1966 hearings, contemporary safety practice thus became principally concerned with how to engineer this second line of defense, shifting the profession's focus away from driver behavior and towards the design of vehicles and roadside hardware.[8] Passive safety begins from the perspective that drivers will err, combined with the observation that there are fewer crashes on Interstates than on other roadways. Collectively, this resulted in the conclusion that "Highways built with high design standards put the traveler in an environment which is fundamentally safer because it is more likely to compensate for the driving errors he *will* eventually make" [emphasis added] (AASHTO, 1974, p. 15).

This perspective is still evident in the most recent edition (2001) of AASHTO's *A Policy on the Geometric Design of Highways and Streets* (the "Green Book"), which states:

> The objective in design of any engineered facility used by the public is to satisfy the public's demand for service in a safe and economical manner. The [highway] facility should, therefore, accommodate nearly all demands with reasonable adequacy and also should not fail under severe or extreme traffic demands . . . every effort should be made to use as high a design speed[9] as practical to attain a desired degree of safety. (pp. 66–67)

Thus, the passive approach attempts to enhance a roadway's safety by designing it to accommodate the safety needs of high-speed, "extreme" driving behavior. This approach hinges on a critical assumption, however: it assumes that drivers who already drive safely will continue to do so when forgiving design values are used, thereby enhancing the overall safety of a roadway by making it safe for not only "average" drivers, but also extreme drivers as well.

While the logic behind the passive approach has a high degree of face validity, it overlooks several important questions: how do average drivers adjust their behavior to forgiving design values? What about specific at-risk subpopulations?[10] Is it possible that by widening lanes and shoulders and eliminating roadside objects, designers are

encouraging "non-design drivers" to adopt behaviors that result in crashes and injuries?

A Simple Empirical Test

With respect to determining the appropriate clear zone for a roadway, the most recent guidance states that "the wider the clear zone, the safer it will be" (Transportation Research Board [TRB], 2003, p. V-43). If this is true, then one would expect livable streetscape treatments to be less safe, in terms of crash frequency and severity, than roadways adopting more forgiving values for lane widths and clear zones. To test this assertion, as well as to build an understanding of the safety effects of livable streets more generally, I examined 5 years (1999–2003) of crash data for Colonial Drive (State Road 50), a state-owned arterial that connects the north end of downtown Orlando, Florida, to its eastern and western suburbs.

While none of Colonial Drive would be regarded as a particularly representative example of a livable street, the 0.9-mile segment that constitutes the northern edge of downtown Orlando (between Orange Avenue and Mills Avenue) includes many of the design features desired by livable streets advocates. Roadside development abuts the sidewalk, which is often uncomfortably narrow at points, but continuous throughout the section. Lane widths are narrower here (11 feet) than on much of the remainder of the roadway, and the segment includes on-street parking and roadside objects that buffer the pedestrian environment. The cross section, curb-to-curb, is roughly 68 feet, including four 11-foot travel lanes, a 10-foot painted median, and two 6.5-foot parking lanes. Roadside objects are offset by 1.5 to 2 feet from the curb (see Figure 2).

To evaluate the safety performance of this segment, it was matched with the nearest 0.9-mile section of Colonial Drive that was similar in terms of cross-sectional characteristics (four lanes and a painted median), posted speed limit, and average daily traffic (ADT) but which used more forgiving values for lane widths and clear zones.

The nearest comparison length was located slightly less than 4 miles east of the livable section described above. As shown in Table 2, the roadways are almost identical in all relevant characteristics of interest—section length, ADT, number of lanes, and median width—while differing principally in terms of lane widths and roadside object offsets. It should be observed that the posted speed limit is slightly higher for the comparison section (45 mph vs. 40 mph), but not substantially so. There is little difference in the average number of crashes per intersection or the mean age of at-fault drivers. Further, the use of a nearby comparison section on the same roadway helps control for the unique characteristics of the driver population, which in this case will include many of the exact same drivers. Holding all of these features constant, if the passive safety assumption holds, there should be fewer mid-block injuries and fatalities on this comparison section.

Comparing Crash Performance

As shown in Table 3, the livable section is safer in all respects. By any meaningful safety benchmark—total mid-block crashes, injuries, or fatalities—there can be little doubt that the livable section is the safer roadway.

A second area of interest for this study is the specific distribution of crash types across the roadways. What are the types of crashes that result in mid-block fatalities and injuries? There were no fatal mid-block crashes on the livable section during the 5-year evaluation period, while 6 occurred along the comparison length of the roadway, 3 of which involved pedestrians. Harmful event data were not provided on the other 3 fatalities.

Pedestrian and bicyclist injuries were likewise higher on the comparison section (see Table 4), which may be partly attributable to the fact that the livable section provides parked cars and fixed objects to buffer pedestrians from oncoming traffic. But do the benefits in pedestrian safety outweigh the hazards these features may pose to errant motorists?

For the livable section, there were 2 injurious crashes involving roadside objects, one involving a tree, and a second involving a parked car. Comparatively, there were 5 injurious crashes involving pedestrians and bicyclists on the comparison section, 3 of which were fatal.

What about the relative roadside hazards these designs might pose? From a passive safety perspective, the comparison section, with a 20-foot clear zone, should be the safer of the two in terms of total injurious collisions with fixed objects. Yet this is also not the case. Not counting pedestrians and bicyclists, there were 3 roadside object-related injuries on the comparison section, versus 2 in the livable section.

Finally, what about motor vehicle collisions? The average number of crashes per intersection were similar between the two study sections. Might the comparison section be at least as safe in terms of two-vehicle mid-block crashes? Again, the answer is no. For rear-end crashes, the crash type most likely to be associated with on-street parking, there were fewer injuries for the livable section. Likewise with injuries associated with head-on crashes, turn-related crashes, and sideswipe crashes. Only angle crashes were comparable, with both sections reporting 6 such injurious crashes during the 5-year evaluation period. In

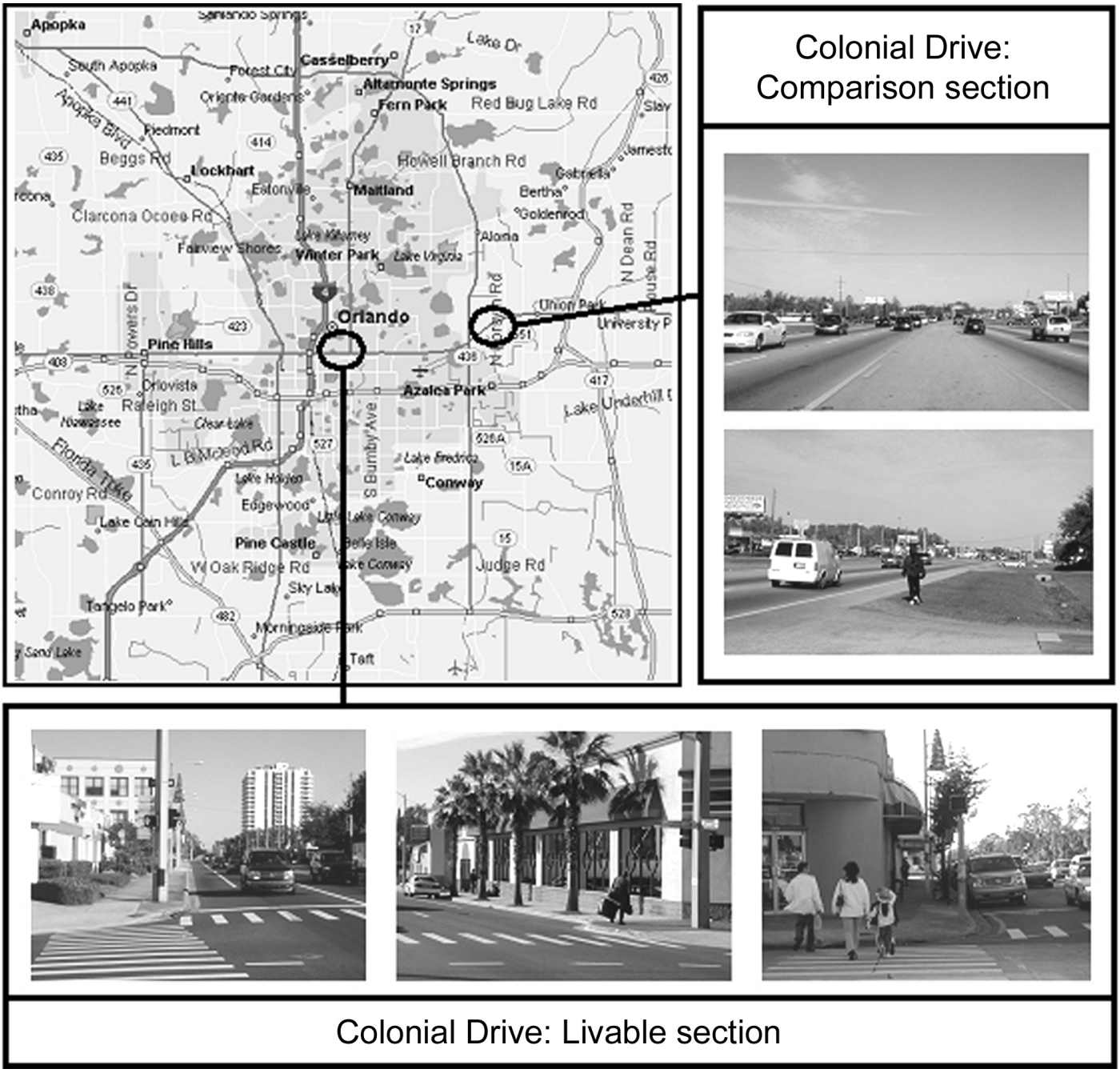


Figure 2. Colonial Drive: livable and comparison sections.

total, 9 more multiple-vehicle mid-block injurious crashes occurred on the comparison section than the livable one.

Comparing the Livable Section to Baseline Roadway Safety Performance

To understand how the livable section of Colonial Drive performed against urban operating conditions along State Route 50, I further compared its crash performance to 5-mile sections of Colonial Drive located on either side of the livable section, thereby capturing the majority of urban and suburban travel along this roadway. While this approach does not control for specific design variations along individual roadway segments, it is useful for determining whether the livable section is more or less safe than one would expect, on average, from the urbanized portion of the roadway as a whole.

Characteristic	Livable section	Comparison section
Length (miles)	0.9	0.9
Average daily traffic (vehicles)	47,000	46,000
Posted speed limit (mph)	40	45
Lanes	4 x 11 ft.	4 x 12.5 ft.
Median	10 ft. painted	10 ft. painted
Shoulder	6.5 ft. parking lane	5 ft. paved shoulder ± 15 ft. runout zone
Avg. crashes per intersection	21	19
Mean age of at-fault driver	28	27

Table 2. Design characteristics of livable and comparison sections of Colonial Drive.

Mid-block crashes	Livable section	Comparison section	Difference (%)
Total	73	82	−11%
Injurious	42	61	−31%
Fatal	0	6	−100%

Table 3. Mid-block crashes on Colonial Drive, 1999–2003.

Crash type	Livable section	Comparison section	Difference
Rear-end	29	35	−6
Head-on	0	1	−1
Angle	6	6	0
Left-turn	1	2	−1
Sideswipe	1	2	−1
Parked car	1	0	1
Pedestrian	0	4	−4
Bicyclist	0	1	−1
Tree/shrubbery	1	0	1
Other fixed object	0	1	−1
Ditch/culvert	0	2	−2
Other/unreported	3	7	−4
Total	42	61	−19

Table 4. Injurious mid-block crashes on Colonial Drive, 1999–2003.

Crashes were normalized by determining the number of crashes per 100 million vehicle miles traveled (VMT), [11] thereby developing a measure of exposure that could be used to directly compare safety performance. Nevertheless, a problem with VMT-based measures is that the relationship between VMT and crashes is not linear (Ivan et al., 1999). This finding may be attributable to the fact that high levels of congestion occurring during peak periods can have the dual effect of increasing the denominator of the measure while simultaneously reducing free-flow travel speeds, the combination of which may result in underestimates of a roadway's actual hazard during low-volume, free-flow operating conditions, such as late-night travel. To address this concern, I also evaluated safety performance based on the number of mid-block crashes per mile, a measure that makes no assumption about the relationship between traffic volumes and crash performance.

As shown in Table 5, the livable section of Colonial Drive is safer, by either measure, than one would expect when examining the 10-mile urban and suburban comparison section as a whole, reporting fewer total mid-block crashes than the comparison length of Colonial Drive, and substantially fewer injurious and fatal crashes.

Trend Identification

To determine whether the safety performance of Colonial Drive might perhaps be part of a broader safety trend, I further examined the crash performance of state arterial roadways traveling through the National Register–designated historic districts of DeLand and Ocala, Florida. Each city has two 0.5-mile sections of state roadways entering its historic district, with all four roadways having dense development adjacent to the travelway, minimum (1.5–2 feet) fixed-object offsets, and, for the two DeLand roadways, on-street parking as well.

These roadways also included posted speed limit reductions of 10 mph or more, thus preventing one-to-one comparisons with adjacent sections. Nevertheless, understanding their safety performance with respect to the urban sections of these roadways as a whole does allow one to evaluate whether such treatments are safer than one would expect from baseline roadway averages, and is extremely useful for determining whether the safety performance of the livable section of Colonial Drive is anomalous, or whether it might perhaps be part of a broader safety trend.

In the absence of detailed field observations, the historic district boundaries were used to determine the boundaries of the livable sections of these roadways, and these sections were then compared against the crash performance of 5-mile sections of the same roadway located on either side of the historic district,[12] thereby permitting a consistent comparison of these roadways both against each other and against Colonial Drive. The individual performance of these roadways, as well as their averages, are reported in Table 6.

Like Colonial Drive, the livable sections were generally safer than their comparison roadways. On average, the historic roadway sections reported somewhat fewer total crashes and substantially fewer injurious crashes. Perhaps most notably, not a single fatal crash was reported for any of these historic roadway sections during the 5-year analysis period.

Individually, two specific results warrant noting. First, while the historic section of Woodland Avenue shows reductions in total and injurious crashes on a per-mile basis, it reports substantially higher crashes and injuries when using a VMT-based metric. In this case, the relatively low level of VMT observed for the historic section when compared to its comparison roadway (17,000 vs. 31,000 ADT) may overestimate its relative hazard. In absolute terms, the number of mid-block injurious crashes on the historic section of Woodland Avenue is identical to that for the other three roadways, with all of the historic sections reporting *exactly* 4 injury crashes over the 5-year analysis period, or 8 injurious crashes per mile.

Pine Avenue, while safer than the comparison roadway overall in terms of injuries and fatalities, nevertheless reports a higher number of total mid-block crashes than the roadway as a whole, although this may in part be attributable to cross-sectional differences. While the majority of State Route 25, of which Pine Avenue is a part, is a four-lane roadway, the 0.5-mile section that travels through Ocala's historic district briefly switches to a six-lane cross section, a factor that has been shown to result in higher numbers of crashes and injuries (Noland & Oh, 2004). The fact that higher total crash rates were not accompanied by higher rates of injurious or fatal crashes is an interesting and potentially important finding.

Reconsidering the Relationship Between Safety and Design

> To reject one paradigm without simultaneously substituting another is to reject science itself. (Kuhn, 1962, p. 79)

While these results seem to contradict conventional design practice, they confirm a trend that many researchers and practicing engineers have observed for some time, but which has received little substantive elaboration: specifically, that clear zones and other forgiving design practices often have an ambiguous relationship to safety in urban environments, and may be associated with declines in safety performance. The best possible explanation for the enhanced safety performance of the livable sections considered in this study is that drivers are "reading" the potential hazards of the road environment and adjusting their behavior in response.

	Mid-block crashes per 100 million VMT			Mid-block crashes per mile		
	Livable section	10-mile comparison	Difference (%)	Livable section	10-mile comparison	Difference (%)
Mid-block crashes						
Total	95	102.0	−6.9%	66	88.0	−25.0%
Injurious	54	69.0	−21.7%	38	59.0	−35.6%
Fatal	0	2.1	−100.0%	0	1.8	−100.0%

Table 5. Mid-block crash performance of Colonial Drive, livable section vs. 10-mile urban comparison section, 1999–2003.

The reason why this subject has not received greater attention in design literature and guidance appears to be that it contradicts the prevailing paradigm of what constitutes safe roadway design. Nevertheless, a behavior-based understanding of safety performance is supported by research and literature in the field of psychology, which has focused on the subject of traffic safety as a means for understanding how individuals adapt their behavior to perceived risks and hazards.

Risk homeostasis theory, as developed by Wilde (1982, 1988, 1994), asserts that individuals make decisions on whether to engage in specific behaviors or activities by weighing the relative utility of an action against its perceived risk. While all actions involve some risk, risk homeostasis theory asserts that individuals will adjust their behavior to maintain a static level of minimum exposure to perceived hazard or harm. With respect to driving behavior, risk homeostasis theory posits that drivers intuitively balance the relative benefits of traveling at higher speeds or engaging in other higher-risk driving behavior against their individual perceptions of how hazardous engaging in such behavior might be. Where hazards are present and visible, such as in the case of livable streetscape treatments, risk homeostasis theory would expect drivers to compensate for this perceived environmental hazard by adjusting their behavior to minimize their exposure to risk.

Nevertheless, risk homeostasis theory would also assert that, *ceteris paribus*, the relative crash performance of a roadway should remain constant along its length, regardless of specific design variations, since any change in perceived hazard will be offset by corresponding adjustments in behavior. Thus, according to risk homeostasis theory, the livable street sections should be no more or less safe than their comparison roadways overall.

Yet as Hauer (1999b) describes, there is an important distinction between *safety*, which is (or should be) an em-

	Mid-block crashes per 100 million VMT			Mid-block crashes per mile		
Roadway	**Historic district**	**10-mile comparison**	**Difference (%)**	**Historic district**	**10-mile comparison**	**Difference (%)**
Pine Ave., Ocala (SR 25)						
Total	36.0	33.6	7.1%	24.0	18.4	30.4%
Injurious	12.0	23.2	−48.3%	8.0	12.7	−37.0%
Fatal	0.0	0.9	−100.0%	0.0	0.5	−100.0%
Silver Springs Blvd., Ocala (SR 40)						
Total	28.7	42.1	−31.8%	16.0	20.0	−20.0%
Injurious	14.4	24.2	−40.5%	8.0	11.5	−30.4%
Fatal	0.0	0.4	−100.0%	0.0	0.2	−100.0%
New York Ave., DeLand (SR 44)						
Total	44.7	68.9	−35.1%	10.0	14.9	−32.9%
Injurious	35.8	52.7	−32.1%	8.0	11.4	−29.8%
Fatal	0.0	4.2	−100.0%	0.0	0.9	−100.0%
Woodland Ave., DeLand (SR 15)						
Total	43.1	26.6	62.0%	12.0	14.3	−16.1%
Injurious	28.7	18.8	52.7%	8.0	10.1	−20.8%
Fatal	0.0	0.7	−100.0%	0.0	0.4	−100.0%
Average						
Total	38.2	42.8	**−10.7%**	15.5	16.9	**−8.3%**
Injurious	22.7	29.7	**−23.6%**	8.0	11.4	−29.8%
Fatal	0.0	1.6	**−100.0%**	0.0	0.5	−100.0%

Table 6. Mid-block crash performance of roadways in historic districts and 10-mile comparison sections, 1999–2003.

pirical measure of crash performance, and *security*, which is an individual's subjective perception of safety (or conversely, perceived exposure to harm). The presence of features such as wider lanes and clear zones would appear to reduce the driver's perception of risk, giving them an increased but false sense of security, and thereby encouraging them to engage in behaviors that increase their likelihood of being involved in a crash event. If so, this explains why the livable streetscape treatments examined in this study resulted in not only fewer fixed-object crashes, but fewer multiple vehicle and pedestrian crashes as well. Such treatments appear to help balance drivers' sense of security with the real levels of risk in their environment, providing them with more accurate information on the appropriate level of caution, and resulting in behavioral adjustments that better prepare them for the potentially hazardous vehicle and pedestrian conflicts that one encounters in urban environments. From the perspective of risk homeostasis theory, the use of high design values is not "forgiving," but is instead "permissive."

Researchers attempting to understand safety anomalies emerging in their work have implicitly suggested a driver's risk perception accounts for their findings. Ossenbruggen et al. (2001) speculated that the better safety performance of urban villages may be attributable to the fact that the roadside environment "warn[s] drivers that they must maintain a low speed and use caution" (p. 496). In explaining why new roadway improvements were shown to result in an increase in crashes and injuries, Noland (2001) suggested that "higher design standards [allow] drivers to increase their speeds on roads and reduce their levels of caution" (p. 24).

Towards a Theory of Positive Design

> . . . competent drivers can be given appropriate information about hazards and inefficiencies to avoid errors. (Federal Highway Administration, 1990, p. 1-1)

The idea that safety can be addressed by focusing on a driver's perception of risk, rather than relying solely on passive engineering principles, is not without precedent in the engineering community. Two important byproducts of the passive safety approach are the related concepts of positive guidance and driver expectancy, which first emerged in the Appendix to the second edition of AASHTO's *Highway Design and Operational Practices Related to Highway Safety* (1974) as a means to address crashes associated with narrow bridges. While emphasizing that the consistent[13] application of freeway standards is the preferred solution for addressing safety at narrow bridges, the guide remarks that "it would take years and billions of dollars to effect such a program" (p. 83).

In an attempt to satisfice a lower-cost, more implementable solution, the guidance proposes that "highway safety can be considerably improved by restructuring the driver's expectancies so that he is prepared for the narrow bridge situation [and] the narrowing of the shoulder and/or roadside . . ." (p. 83). The guidance then proceeds to detail how to adequately sign and mark the approach to the "restricted" condition of a narrow bridge.

To date, positive guidance has focused largely on the use of pavement markings and signs to convey safety information, and there has been relatively little advancement in this area since 1990, when the most recent edition of the Federal Highway Administration's (FHWA's) *A Users Guide to Positive Guidance* was published.[14] Nevertheless, it may be time to resurrect this concept, particularly as it may relate to the physical design of highways and streets.

A positive approach to transportation design would seem to explain the emerging safety anomalies the passive approach simply cannot account for, such as Naderi's (2003) findings on aesthetic streetscape treatments or the livable street examples included in this study. It also explains why narrowings and chicanes, two traffic calming applications that modify the roadside in a manner that passive safety suggests should increase crashes and injuries, have been shown to result in substantial (74%–82%) crash reductions (Zein et al., 1997). Indeed, all traffic calming measures appear to reduce accidents by slowing traffic and/or increasing driver caution (Ewing, 1999), leading European designers to view them not as "livability" features but as safety countermeasures (Skene, 1999).

A Positive Approach to the Design of Urban Streets

The passive approach promotes designs intended to support high-speed operating behavior, and then attempts to mitigate a roadway's hazards through the use of signs and pavement markings. The problem that emerges, however, is that signs and roadways are often communicating contradictory information. The result is that the majority of drivers in urban areas disregard posted speed limits, and seem to learn to disregard road signs altogether, even when they display information that is essential to their safety (Chowdhury et al., 1998; Fitzpatrick, Carlson, et al., 2003; Fitzpatrick, Shamburger, et al., 1996; Kubilins, 2000; Tarris et al., 2000). Further, even when drivers are deliberately attempting to obey speed restrictions, they instinctively increase their operating speed to their perception of a roadway's safe speed when their concentration is focused on something other than actively monitoring their vehicle's

speedometer (Recarte & Nunes, 2002). This latter finding suggests that even conscientious drivers may be unable to comply with posted speed limits when roadways are designed for higher-speed operation.

A key point of departure for positive design is that it openly recognizes that drivers use the total information provided by their environment—not just posted speed limits—and strives to take advantage of these opportunities to provide drivers with the information they need to operate their vehicles safely and appropriately. On this subject, Our European counterparts, with markedly safer roadways than the United States,[15] have developed a potentially valuable alternative.

European designers use an "environmental reference speed" when designing a roadway, beginning the design process by tightly specifying the desired operating speed of a roadway, and then using this intended operating speed as the roadway's design speed, providing posted speed limits that match (FHWA, 2001; Lamm et al., 1999). Roadways are thus designed to be self-explaining and self-enforcing, conveying a single and consistent message to the driver on safe operating behavior.

Further, European designers view high-speed driving as incompatible with the safe operation of urban roadways. For all streets with any concentration of roadside development or anticipated pedestrian activity, design speeds are severely restricted, rarely exceeding 50 km/h (31 mph). As a 2001 FHWA scan of European design practice concluded:

> [European] countries have very high safety goals (ranging from zero fatalities to reduction of more than 40 percent for all crashes) that guide the design approach and philosophy. To achieve these goals, planners are willing to provide roadways that self-enforce speed reductions, potentially increase levels of congestion and promote alternative forms of transportation. This approach contrasts with the U.S. design philosophy, in which wider roads are deemed safer, there is a heavier reliance on signs to communicate the intended message, and there is a lower tolerance for congestion and speed reduction. (FHWA, 2001, p. viii)

The European approach is achievable because designers explicitly recognize that a roadway's environmental context plays a key role in determining its safe design and operation, and they have developed design practices aimed at linking specific design values to their corresponding physical and operational contexts. German designers, for example, use a 30-celled functional classification system that accounts for not only mobility and access, but also variations in a roadway's design environment and the needs of a diverse set of user groups (Lamm et al., 1999). Thus, practicing designers are provided with clear guidance on the safe and appropriate design of roadways that address design needs for a range of physical and environmental contexts.

Conversely, U.S. practice applies an extremely coarse, three-tiered functional classification system that categorizes roadways exclusively according to their vehicle access or mobility functions (AASHTO, 2001), resulting in the problem that many of the urban roadways classified as minor arterials serve a variety of purposes other than higher-speed mobility functions. Roadways designated as minor arterials cover a wide range of physical environments, and there is little guidance detailing which design values are most appropriate in each context (see Figure 3). Indeed, the lowest recommended design speed for an urban minor arterial in the United States (30 mph) is simultaneously the *highest* design speed that would be applied on a similar roadway in a European city (AAHSTO, 2001; Lamm et al., 1999).

Despite a host of problems associated with applying the U.S. functional classification system in an urban environment (de Cerreno & Pierson, 2004; Forbes, 2000; Kubilins, 2000; Meyer & Dumbaugh, 2004), many design engineers have made notable strides in this area through the use of context-sensitive solutions, an approach that incorporates stakeholders in the project design and development process (FHWA, 1997; TRB, 2002). One problem that emerges, however, is that determining whether a specific design approach is appropriately safe is ultimately a matter of professional engineering judgment, not an outcome of public involvement activities. On this subject, designers are forced to navigate the uncharted waters of urban road safety alone.

And increasingly, many practicing designers are doing so. There are a growing number of examples of design engineers who have chosen to thoughtfully strike out on their own, moving beyond the conventional definition of "safe" design practice to develop new strategies for addressing the twin goals of safety and livability. Five such examples are included in this study alone. Yet any success in this area has occurred in spite of passive safety practices, not because of them. It is the obligation of future researchers to begin to more fully develop our understanding of how to safely design urban roadways, and to ensure that this information is better disseminated throughout the profession. A positive approach to transportation design would appear to be a key means of doing so.

Finally, this study does not suggest that certain urban roadways can not or should not be designed to address mobility needs. But it does suggest that we must move

beyond the assumption that the use of "forgiving" design values necessarily equates to enhanced safety, and to begin reconsidering the role that driver behavior may have on a roadway's safety performance, particularly in urban environments. Substantial opportunities for enhancing both safety and livability remain to be explored.

Safe Streets, Livable Streets

At the most fundamental level, the major tension in the design of urban roadways does not appear to be a matter of balancing safety and livability objectives. There is little evidence to support the claim that "livable" streetscape treatments are less safe than their more conventional counterparts, and the weight of the evidence suggests that they can possibly enhance a roadway's safety performance. Instead, the more basic problem appears to be that safety and livability objectives are often in direct conflict with the overarching objective of mobility, and its proxy—speed.

The passive approach to transportation safety began with the observation that the Interstate Highway System produced fewer crashes and injuries than other roadway classes, and attributed this safety performance to the use of higher-speed, more "forgiving" design values. Yet it must be recognized that the safety performance of the Interstate system is probably better explained by the fact that these roadways physically restrict access, channel vehicle movements, and limit their use to a single user type—motorists—than because they permit higher operating speeds.

Conventional safety practice attempts to superimpose these high-speed, limited-access design characteristics on other roadway types, but it is not at all clear that these designs are either safe or appropriate in an urban context. At the most basic level, the primary function of cities, and thus the streets that serve them, is to concentrate compatible developments and activities together and to encourage a high degree of access between them, traditionally through nonmotorized modes. High-speed, limited-access roadways are inherently antithetical to these purposes.

I have argued that many of the safety concerns that emerge on urban streets result from design practices that fail to link a roadway's design to its environmental context, thereby providing motorists in urban environments with a false sense of security and increasing their potential exposure to crashes and injuries. I have further provided a theoretical framework that better accounts for the safety anomalies one observes when examining the literature and data on the crash performance of urban roadways. Yet theory is only the first step. There is a clear and demonstrated need to better develop our professional understanding of the relationship between driver behavior and transportation safety, as well as to enhance our overall approach to the design of urban roadways. This study thus concludes with the hope that by better understanding the relationship between design, driver behavior, and safety, we can design roadways that are not only safe, but also livable.

Figure 3. Three urban minor arterials.

Acknowledgments

This article benefited from the comments and recommendations of many colleagues. Particularly, I would like to thank Michael Meyer and Michael Dobbins from the Georgia Institute of Technology; Susan Herbel with the TSS Group; Jane Lim-Yap, Ian Lockwood, and Walter Kulash at Glatting-Jackson; Jonathan Lewis at Jordan, Jones and Goulding; Stephanie Macari with the Montgomery County Planning Commission; and Quentin Kruel with Long and Foster. I would also like to especially thank *JAPA*'s editors and anonymous reviewers, who provided invaluable comments on an earlier draft of this article.

Notes

1. In conventional engineering parlance, all roadways are referred to as *highways*. Conventional, high-speed highways are referred to as *freeways*.

2. While the AASHTO (2001) Green Book permits the use of a 1.5-foot "operational offset" on urban arterials, it is important to recognize that this is intended only to prevent motor vehicles from hitting their mirrors on roadside objects during normal operating conditions, and is not intended or perceived as having a meaningful relationship to safety. As stated in the Green Book: "Clear roadside design is recommended for urban arterials wherever practical" (p. 485).

3. The finding with the potentially most profound influence on roadside safety is also the one that receives the least attention. The authors noted that "curves were highly over-represented in tree accidents. Almost 59% of tree accidents were related to a curve. This is startlingly high considering that probably no more than 5% of all street mileage in the city of Huntsville is curved" (Turner & Mansfield, 1990, p. 97). In response to this finding, the authors recommended prioritizing tree eliminations at curves. While such an approach may go a long way towards reducing injuries in run-off-road events, it fails to ask the potentially more important question: why are run-off-roadway events more likely to occur at curves in the first place? It would seem unlikely that this remedial action—eliminating the tree—will have any effect on eliminating the run-off-roadway event, which may nevertheless result in an injurious crash, such as a rollover, regardless of whether a tree is present. As evidenced in Milton and Mannering (1998), the problem is not the curve itself, but a curve that it is preceded by a straight (high-speed) approach.

4. Hauer (2000) does note that "I am not convinced that if research was done on current data, that 12-foot lanes would be found to be less safe than 11-foot lanes. Much has changed since then; trucks grew to be larger and research methods improved. However, at the time the Policy was written, the aforementioned findings by respected researchers should have sounded alarm" (p. 12).

5. While Noland and Oh's (2004) study focused primarily on rural observations, two specific findings bear mentioning. Shoulders had an ambiguous relationship to safety, with wider shoulders being associated with a decrease in total crashes but increases in fatal ones. While these findings do not directly address safety in urban environments, they do suggest that increasing shoulder widths may increase vehicle speeds, thereby increasing crash severity, if not frequency.

6. My treatment of this topic skirts over a rich and interesting history that deserves a more thorough treatment than can be given here. Interested readers should are encouraged to see Weingroff (2003) and Gladwell (2001), both of which are not only highly informative, but surprisingly compelling.

7. Practicing engineers will undoubtedly recognize the similarity between Nader's hypothetical "drunk looking out the window" and the definition of the "design driver" used in contemporary design practice.

8. This is evidenced in the fact that while our methods for the crash testing of vehicles and roadside hardware have become increasingly elaborate in the past 40 years (see Transportation Research Board, 1993, for current test standards), there has been little advancement in our understanding of the behavioral factors that cause crashes to occur (Kanellaidis, 1996; Noland, 2001).

9. While a full treatment of the subject of design speed is beyond the scope of this study, the important fact is that a roadway's design speed is the controlling element in its design. Once a design speed is selected, all other geometric features, such as lane widths and clear zones, are designed to conform to the adopted design speed. Thus, higher design speeds encourage the use of higher minimum values for all other geometric features as well.

10. Examining Fatality Analysis Reporting System (FARS) data for minor arterials, collectors, and local roadways is revealing. In 2002, for example, half of all individuals killed in a fixed-object crash on these road classes were between the ages of 16 and 25, and fully 40% of the total crashes involved males in this age group. Females account for less than a third of the fatalities in all age brackets except the 71 and older group, where male and female fatalities equalize, undoubtedly the result of the fact that at these ages, personal motor functions and reaction times begin to decline. When one considers this information holistically, it suggests that fixed-object fatalities may not be a design problem as much as they are a reflection of broader demographic and sociocultural factors, such as a propensity of young males to engage in higher-risk behavior.

11. To calculate a roadway's VMT for the 5-year study period, I determined average ADT for each roadway milepost, and then used the median ADT to derive an overall estimate of VMT for the road segment. The median was selected as a better measure of central tendency than the average because several small roadway segments had unusually high ADTs, thus skewing the overall averages. Once median ADT was determined, VMT was calculated as: VMT = Median ADT × 365 × 5 × Section Length.

12. The exception is Pine Avenue (State Road 25) in Ocala. Only 2.1 miles of roadway were available for the northern comparison section because a substantial (14-mile) segment is currently off the state system. To acquire 10 miles of comparison roadway data, I used averages for a 2.1-mile section to the north and a 7.9-mile section to the south.

13. *Design consistency*, a phrase often used by designers to discuss how they address safety through design, also emerged in the 1974 guide, which states: "consistency in design standards is desirable on any section of road, because problem locations are generally at the point where minimum design treatment is used" (p. 15). Restated another way, design consistency, as it was originally conceived, encourages the consistent adoption of high design values.

14. In the 1994 and 2001 editions of AASHTO's Green Book, the sections dealing with these subjects contain no data, nor has a word been changed.

15. A few statistics bear mentioning. In 1966, the year that passive safety principles first became embedded in contemporary practice, the U.S. had fewer transportation-related fatalities per capita (26 per 100,000 population) than all other countries except Great Britain (15 per 100,000). By 2000, the U.S. (15 fatalities per 100,000) remained behind Great Britain (6 per 100,000), but had also fallen behind the entirety of the European Union (11 per 100,000), Australia (10 per 100,000), Japan (8 per 100,000), and, indeed, the rest of the developed world (NHTSA, n. d.; World Health Organization, 2004). While these statistics are alarming, they also suggest that promising new opportunities for enhancing transportation safety remain to be explored.

References

American Association of State Highway Officials. (1967). *Highway design and operational practices related to highway safety*. Washington, DC: Author.

American Association of State Highway and Transportation Officials. (1974). *Highway design and operational practices related to highway safety*. Washington, DC: Author.

American Association of State Highway and Transportation Officials. (1994). *A policy on geometric design of highways and streets* (3rd ed.). Washington, DC: Author.

American Association of State Highway and Transportation Officials. (1997). *Highway safety design and operations guide*. Washington, DC: Author.

American Association of State Highway and Transportation Officials. (2001). *A policy on geometric design of highways and streets* (4th ed.). Washington, DC: Author.

American Association of State Highway and Transportation Officials. (2002). *Roadside design guide*. Washington, DC: Author.

Chowdhury, M. A., Warren, D. L., Bissell, H., & Taori, S. (1998, February). Are the criteria for setting advisory speeds on curves still relevant? *ITE Journal*, 32–45.

de Cerreno, **A. L. C.**, & Pierson, I. (2004). *Context sensitive solutions in large central cities*. New York: Rudin Center for Transportation Policy and Management.

Duany, A., Plater-Zyberk, E., & Speck, J. (2000). *Suburban nation: The rise of sprawl and the decline of the American dream*. New York: North Point Press.

Ewing, R. (1996, March). *Pedestrian and transit friendly design*. Tallahassee: Public Transit Office, Florida Department of Transportation.

Ewing, R. (1999). *Traffic calming state-of-the-practice*. Washington, DC: Institute of Transportation Engineers.

Federal Highway Administration. (1990, September). *A user's guide to positive guidance* (3rd ed.; Report No. FHWA-SA-90-017). Washington, DC: U.S. Department of Transportation.

Federal Highway Administration. (1997). *Flexibility in highway design* (Publication No. FHWA-PD-97-062). Washington, DC: U.S. Department of Transportation.

Federal Highway Administration. (2001). *Geometric design practices for European roads* (Publication No. FHWA-PL-01-026). Washington, DC: U.S. Department of Transportation.

Fitzpatrick, K., Carlson, P., Brewer, M., & Wooldridge, M. D. (2003). Design speed, operating speed, and posted speed limit practices. In Transportation Research Board, *82nd Annual Conference Proceedings* [CD-ROM]. Washington, DC: Transportation Research Board.

Fitzpatrick, K., Shamburger, B., & Fambro, D. (1996). Design speed, operating speed, and posted speed survey. *Transportation Research Record, 1523*, 55–60.

Florida, R. (2002). *The rise of the creative class: And how it's transforming work, leisure, community and everyday life*. New York: Basic Books.

Forbes, G. (2000, December). Urban roadway classification: Before the design begins. In *Urban Street Symposium Conference Proceedings* (Transportation Research E-Circular Number E-C019), B6/1–B6/8.

Frank, L. D., Engelke, P., & Schmid, T. (2003). *Health and community design: The impact of the built environment on physical activity*. Washington, DC: Island Press.

Frank, L. D., Stone, B., & Bachman, W. (2000). Linking land use with household vehicle emissions in the Central Puget Sound: Methodological framework and findings. *Transportation Research D, 5*, 173–196.

Gladwell, M. (2001, June 11). Wrong turn: How the fight to make America's roadways safer went off course. *New Yorker*, 50–61.

Hauer, E. (1999a). *Safety in geometric design standards*. Retrieved January 11, 2005, from http://members.rogers.com/hauer/Pubs/09Safety%20in%20Geometric%20Design.pdf

Hauer, E. (1999b). Overview. In Institute of Transportation Engineers, *The traffic safety toolbox: A primer on traffic safety* (pp. xi–xvi). Washington, DC: Institute of Transportation Engineers.

Ivan, J., Raghubhushan, N., Pasupathy, K., & Ossenbruggen. P. J. (1999). Differences in causality factors for single and multi-vehicle crashes on two-lane roads. *Accident Analysis and Prevention*, *31*, 695–704.

Jacobs, A. B. (1993). *Great streets*. Cambridge, MA: MIT Press.

Jacobs, J. (1961). *Death and life of great American cities*. New York: Modern Library.

Kanellaidis, G. (1996, January/February). Human factors in highway geometric design. *Journal of Transportation Engineering*, 59–66.

Kubilins, M. A. (2000, December). Designing functional streets that contribute to our quality of life. In *Urban Street Symposium Conference Proceedings* (Transportation Research E-Circular Number E-C019), B3/1-B3/5.

Kuhn, T. S. (1962). *The structure of scientific revolutions* (3rd ed.). Chicago: University of Chicago Press.

Kratzke, S. R. (1995, February). *Regulatory history of automatic crash protection in FMVSS 208*. Paper presented at the Society of Automotive Engineers Congress and Exposition, Detroit, MI.

Lamm, R., Psarianos, B., & Mailaender, T. (1999). *Highway design and traffic safety engineering handbook*. New York: McGraw Hill.

Lee, J., & Mannering, F. (1999, December). *Analysis of roadside accident frequency and severity and roadside safety management*. Olympia: Washington State Department of Transportation.

McLean, J. (2002). Review of the development of US roadside design standards. *Road Transport and Research*, *11*(1), 29–41.

Meyer, M. D., & Dumbaugh, E. (2004, July). *Institutional and regulatory factors related to non-motorized travel and walkable communities* (Report Commissioned by the Transportation Research Board and the Institute of Medicine). Available at: http://trb.org/downloads/sr282papers/sr282paperstoc.pdf

Milton, J., & Mannering, F. (1998). The relationship among highway geometries, traffic-related elements and motor-vehicle accident frequencies. *Transportation*, *25*, 395–413.

Nader, R. (1965). *Unsafe at any speed: The designed-in dangers of the American automobile*. New York: Grossman.

Naderi, J. R. (2003). Landscape design in the clear zone: The effects of landscape variables on pedestrian health and driver safety. In Transportation Research Board, *82nd Annual Conference Proceedings* [CD-ROM]. Washington, DC: Transportation Research Board.

National Highway Traffic Safety Administration. (n. d.). *Fatality Analysis Reporting System (FARS) web-based encyclopedia*. Available at: http://www-fars.nhtsa.dot.gov/

Noland, R. B. (2001). Traffic fatalities and injuries: Are reductions the result of "improvements" in highway design standards? In Transportation Research Board, *80th Annual Conference Proceedings* [CD-ROM]. Washington, DC: Transportation Research Board.

Noland, R. B. (2003). Traffic fatalities and injuries: The effects of changes in infrastructure and other trends. *Accident Analysis and Prevention*, *35*, 599–611.

Noland, R. B., & Oh, L. (2004). The effect of infrastructure and demographic change on traffic-related fatalities and crashes: A case study of Illinois county-level data. *Accident Analysis and Prevention*, *36*, 525–532.

Ossenbruggen, P. J., Pendharkar, J., & Ivan, J. (2001). Roadway safety in rural and small urbanized areas. *Accident Analysis and Prevention, 33*, 485–498.

Recarte, M. A., Nunes, L. (2002). Mental load and loss of control over speed in real driving: Towards a theory of attentional speed control. *Transportation Research Part F*, *5*, 111–122.
Rosenberg, C. E. (1962). *The cholera years*. Chicago: University of Chicago Press.
Skene, M. (1999). Traffic calming on arterial roadways? In Institute of Transportation Engineers, *69th Annual Meeting Compendium of Technical Papers* [CD-ROM]. Washington, DC: Institute of Transportation Engineers.
Tarris, J. P., Mason, Jr., J. M., & Antonucci, N. (2000). Geometric design of low-speed urban streets. *Transportation Research Record*, *1701*, 95–103.
Transportation Research Board. (1993). *Recommended procedures for the safety performance evaluation of highway features* (NCHRP Report 350). Washington, DC: National Research Council.
Transportation Research Board. (2002). *A guide to best practices for achieving context sensitive solutions* (NCHRP Report 480). Washington, DC: National Research Council.
Transportation Research Board. (2003). *Guide for addressing run-off-road collisions* (NCHRP Report 500, Vol. 6). Washington, DC: National Research Council.
Turner, D. S., & Mansfield, R. R. (1990). Urban trees and roadside safety. J*ournal of Transportation Engineering*, *16*(1), 90–103.
Viano, D. C. (2002). Lap-shoulder belts: Some historical aspects. In D. Viano (Ed.), *Seat belts: The development of an essential safety feature* (pp. 1–40). Warrendale, PA: Society of Automotive Engineers.
Weingroff, R. F. (2003). *President Dwight D. Eisenhower and the federal role in highway safety*. Retrieved January 11, 2005, from http://www.fhwa.dot.gov/infrastructure/safetypr.htm
Wilde, G. J. S. (1982). The theory of risk homeostasis: Implications for safety and health. *Risk Analysis*, *2*, 209–225.
Wilde, G. J. S. (1988). Risk homeostasis theory and traffic accidents: Propositions, deductions and discussion of dissension in recent reactions. *Ergonomics*, *31*(4), 441–468.
Wilde, G. J. S. (1994). *Target risk*. Toronto: PDE Publications.
World Health Organization. (2004). *World report on road traffic injury prevention*. Retrieved January 11, 2005, from http://www.who.int/violence_injury_prevention
Zein, S. R., Geddes, E., Hemsing, S., & Johnson, M. (1997). Safety benefits of traffic calming. *Transportation Research Record, 1578*, 3–10.

Counterpoint

J. L. Gattis
Gattis is a professor at the Mack-Blackwell Transportation Center, University of Arkansas, Fayetteville.

It has taken many decades for roadway designers to begin to recognize that how road and road environments are designed affects safety, and to identify what particular features enhance or detract from safety in a given environment. This process is still evolving. Historically, there has been a tendency for those funding research to focus on rural or high-speed environments, and on pavements and structures. One outcome of the resulting underemphasis on safety and urban design concerns, as author Eric Dumbaugh identified in this article, is the problem with the published research about urban roadside design in the U.S.: it is limited in both scope and quantity. With these limitations, it is understandable that city street designers extrapolate from principles learned in a rural highway environment. They may not be standing on the firmest ground when they do this, but they judge that it is the best ground they have.

While the author's initial focus is on urban roadside design, he eventually broadens the scope of the article to consider underlying philosophies and assumptions of why drivers choose a certain speed or exhibit other behaviors. He and I agree on certain points, such as that current research is inadequate and a better understanding of urban roadway design and driver behavior interactions is needed, and that other paradigms may bear consideration. However, I question some of his statements in the article:

- In discussing the Huntsville study (Turner & Mansfield, 1990), the author states ". . . it does not lead to the conclusion that eliminating trees . . . will have any effect on a roadway's safety. Such conclusions can only be made by examining the actual crash performance of eliminating trees in urban areas. . . ." Would not a comparison of roadways similar except for the absence or presence of roadside objects such as trees constitute a valid comparison?
- Does the Toronto study (Naderi, 2003) actually show that trees in concrete planters resulted in crash reduction, or that they were instead *associated* with a reduction? While inferences from association can be valid, they do not always equate with causality.
- Contrary to the author's claims, I believe that growing awareness of the need to engineer safety into roadways did not necessarily shift the focus away from driver behavior, but rather expanded the focus to be more inclusive.
- The author suggests that an active approach to safety —constraining the roadway to communicate the need to slow down—might be more effective than the passive approach, which accommodates and perhaps encourages "extreme driving behavior." It is misleading to state that the passive approach attempts to accommodate high-speed, extreme behavior. Speed studies typically reveal that most drivers on a given roadway fall within a rather narrow band of speeds. When roadway designers design for the 85th or 90th percentile speed, they are designing for a speed that is within a few miles per hour of what most drivers choose to drive at, which is hardly extreme. For example, refer

to the accompanying graph, showing the plotted cumulative speed distribution from five city streets in Fayetteville, Ft. Smith, and Little Rock, Arkansas. There is approximately a 3- to 4-mph difference between the 85th percentile speed and the mean speed, which means there is very little difference between designing for the 85th percentile driver and designing for the average driver.

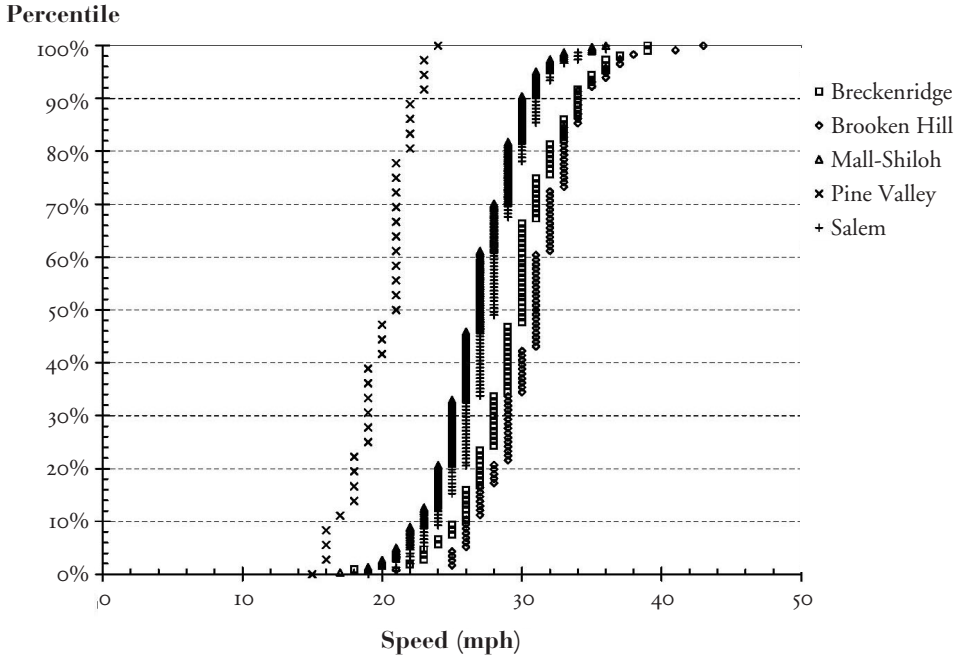
- The author's appeal to risk homeostasis theory employs an *a priori* assumption. First, we need to question whether this theory applies to driving behavior. Observation would suggest there is elasticity in the amount of risk drivers accept, since drivers seem to be willing to increase risk to achieve some reward, such as saving time. Used in this context, this theory almost suggests purposefully increasing the driving hazard in order to improve safety. If we wanted to discourage people from running in grocery store aisles, would we throw down more banana peels?

It should be noted that some recent American research has tried to examine why drivers choose a certain speed in an urban environment, and what factors might communicate to them that they should slow down, but this is a difficult issue to study, much less to resolve. For the present, we are left with conflicting concepts about what effects certain design features will have on the safety of a given urban street. To better understand where and under what conditions various urban aesthetic streetscape treatments are benign or even helpful, resources must be reallocated to improve both urban roadway data systems and safety analysis.

A problem one has with trying to draw conclusions from limited and sometimes seemingly contradictory studies is that of comparing apples to oranges. Research suggests that crash rates are affected by multiple factors, such as traffic volume, width, speed, presence of parking, type of roadside development, and access frequency. Crash studies do not always consider these nuances, but due to the effort needed to have a suitable sample size, it is certainly understandable that only some factors are accounted for. Even in the author's own data, there were somewhat mixed results (e.g., Woodland Avenue in DeLand, Florida). If access frequency for these roadways were to be factored in, still a different finding could have appeared. In short, more context-sensitive research is a prerequisite for context-sensitive design.

Also not to be overlooked in a discussion of the author's initial issue is the fact that there can be other problems with roadway landscaping. Motorists pulling out of side streets and driveways encounter landscaping that has been installed in such a way that it obstructs their view of oncoming traffic. Also, landscaping in the wrong place can restrict motorists' ability to see pedestrians or traffic-control devices.

Perhaps there is another lesson to learn from the Stonex report. What is most often referenced from the



Cumulative speed distribution for five city streets in Arkansas.

report of GM Proving Ground experience is the 30-foot clear zone, but what is overlooked is perhaps more significant. Stonex reported that even with professional drivers on a closed course, with a statistical probability drivers would sooner or later lose control and have an accident. A society that understands this lesson recognizes that drivers are human and sooner or later make mistakes, and tries to incorporate safeguards into roadway design.

Livable streets advocates sometimes ignore the fact that mobility is also a part of quality of life. In the American cities I am familiar with, only a small fraction of the streets (the major and minor arterials) are intended for higher volumes and speeds, while the great majority of the street miles are for lower volumes and speeds. This small percentage of arterial streets is all that people have to rely on to get to their jobs, schools, and other destinations safely and without delay. Policies and design features that impede travel on the few available corridors of mobility, or make travel more dangerous, adversely affect the quality of life for all people.