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Crashes on and Near College Campuses: A Comparative Analysis of Pedestrian and Bicyclist Safety

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Problem, research strategy, and findings: College campuses are multimodal settings with very high levels of walking and biking in conjunction with high levels of vehicular traffic, which increases risks for bicyclists and pedestrians. In this study, we examine crash data (both police reported and self-reported) and urban form data from three U.S. campuses to understand the spatial and temporal distribution of crashes on the campuses and their immediate periphery. To account for underreporting of pedestrian and bicycle crashes, we developed and circulated an online survey, which helped identify collision hotspots across the three campuses. We then studied these locations to determine their characteristics, generate a typology of campus danger zones, and recommend design and policy changes that could improve pedestrian and cycling safety. We find a significant underreporting of crashes, and unequal spatial and temporal distributions of campus crashes. We identify three particular types of danger zones for pedestrians and cyclists: campus activity hubs, campus access hubs, and through traffic hubs. Injuries tended to be more serious for those crashes taking place on campus peripheries.

Takeaway for practice: The intermingling of motorized and non-motorized modes creates significant opportunities for crashes. Planners should be aware of the existing underreporting and give special attention to the three types of danger zones. In addition to the recommendations of the literature for the creation of campus master plans for walking and biking, campuses should conduct safety audits and surveys to identify hotspots and consider specific design improvements for each of the three danger zones to lessen modal conflict.

Keywords: college campuses, pedestrian safety, bicycle safety

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College campuses encompass specific physical structure and social characteristics. They can be thought of as distinct communities; however, they interact with and affect their surrounding neighborhoods as they offer off-campus housing, generate traffic, and impact parking (Balsas, 2003). Campuses draw large numbers of people and are often major employers for a city (Warren, Davidson, Cervenka, Davey, & Parsons, 2004), thus requiring infrastructure that can accommodate large volumes of commuters (Whalen, Páez, & Carrasco, 2013). While some trips to and from the campus involve commutes by private vehicle or public transit, many originate from nearby locations and are better suited for walking and biking. The result is a multimodal environment with high levels of walking and biking in conjunction with high levels of vehicle traffic. This coexistence of multiple transportation modes in a bounded setting gives planners the opportunity to study and address safety challenges and the inherent conflict generated by the interface of different modes. Since many cities now try to create "complete streets" and promote greener modes of transportation, the safe accommodation of multiple modes should be of concern not only for campus planning but for city planning as well.

Traffic safety is, indeed, an imminent and justified concern for pedestrians and cyclists on the campus but also beyond the campus environment.[1] In a survey conducted by the Los Angeles County Metropolitan Transportation Authority, most respondents identified safety concerns as the primary obstacle to cycling (Los Angeles County Metropolitan Transit Authority, 2004). The probability of a pedestrian or bicyclist being injured or killed when colliding with a car is respectively 36.9 and 14.9 times greater than the probability of an injury or fatality for the vehicle occupant (Grembek & Ragland, 2012). Crashes between pedestrians and bicycles may also result in injury, but only anecdotal knowledge exists of the conflicts generated by the coexistence of these two modes.

Crash data typically draw from police reports, but reporting a crash is less likely if there are no injuries, there is little property damage, or only one party is involved, all of which result in significant underreporting of crashes involving pedestrians or cyclists (Reynolds, Harris, Teschke, Cripton, & Winters, 2009; U.S. Department of Transportation, 2010). A survey of 822 cyclists in Los Angeles found that 30% had been involved in a crash or accident without reporting it (Lantz, 2010).

To address these issues and gaps, this study examines pedestrian and bicycle safety on three campuses and their immediate peripheries: University of California, Berkeley (UCB), University of California, Los Angeles (UCLA), and California State University, Sacramento (CSUS). We hypothesize that the coexistence of multiple travel modes would generate significant opportunities for crashes between them (including the much-understudied cases of pedestrian–bicycle collisions); that these crashes would be differentially allocated spatially and temporally; that there would be differences between the predominant type of crashes in the campus periphery versus the campus area; and that built environment characteristics would play a significant role in the causation of crashes. We thus ask the following questions:

a) What is the spatial and temporal distribution of pedestrian and bicycle crashes at each campus?
b) To what extent is there underreporting of crashes in public crash databases?
c) To what extent do characteristics of the built environment contribute to the incidence of pedestrian and bicycle crashes in and around campus locations?
d) What strategies may increase pedestrian and cycling safety on campuses?

In this study, we give an overview of the literature on pedestrian and bicycle safety on campuses, then provide comparative data for the spatial and temporal distribution of pedestrian and bicycle crashes at the three campuses. We also report findings from an online survey, and analyze spatially the reported crashes and perceived hazardous locations. Last, we discuss policy and design changes for safety enhancements on and around college campuses.

Traffic Safety on College Campuses: Brief Literature Review

In the last decade there has been a burgeoning literature on pedestrian and bicycle safety, but only a few studies have focused on campus environments. An early study about campus traffic problems finds that pedestrians and bicyclists are present both within and around the campus, but motor vehicles are more abundant at the campus periphery; it suggests that pedestrians and bicyclists should be a priority when considering campus design (Haines, Kochevar, & Surti, 1974). Other researchers recommend the separation of pedestrians, bicyclists, motorists, and transit services on campuses to reduce intermodal interactions, and hence points of conflict and crash frequency (Dobbs, 2009; Guyton, 1983). Spatial constraints, however, often prevent such modal separation. In addition, a common issue on urban campuses is that as they grow, coordination with the city's transportation network does not always occur, and traffic problems arise (Dobbs, 2009).

Rodriguez-Seda (2008) studied multiple university campuses focusing on traffic demand and supply management and education/enforcement. With regards to demand management, he suggests removing vehicles from core campus areas. One consequence to consider, however, is that although pedestrian-only zones can improve safety and aesthetics on campus, they can cause congestion on surrounding streets and create hardships on businesses that rely heavily on vehicular traffic.

Safe bicycling requires proper facilities to accommodate the specific needs of bicyclists. Many college campuses lack bicycle paths and lanes, intersection treatments, signage, and bicycle parking (Balsas, 2003). Violation of traffic laws may happen in different transportation environments; however, "college-age youth's propensity to ride outside the routes designated for bicycles and to ignore

Table 1. Literature suggestions for safer campuses.

Proposed actions and strategies
• Development of short-term and long-term transportation plans for the campus (Benekohal et al., 2007)
• Establishment of diverse traffic safety committee to discuss transportation safety related issues (Benekohal et al., 2007)
• Attention-grabbing signage at all main vehicular gateways to campus; educational sings and markings for pedestrians and cyclists (Benekohal et al., 2007; Guyton, 1983; Haines et al., 1974; Zegeer, Seiderman, et al., 2002)
• Intersections and midblock crosswalks with distinct features in terms of texture and color, to remind motorists that they are in a campus setting (Benekohal et al., 2007; Rodriguez-Seda, 2008; Zegeer, Seiderman, et al., 2002)
• Closure of inner-campus streets; conversion to pedestrian-only zones (Benekohal et al., 2007; Guyton, 1983; Haines et al., 1974; Rodriguez-Seda, 2008)
• Reduced usage of personal vehicles on campus (limiting number of student parking permits; giving incentives for employee rideshare; providing priority parking for carpools and vanpools) (Guyton, 1983; Rodriguez-Seda, 2008)
• Development of proper bicycle network (Benekohal et al., 2007; Guyton, 1983; Haines et al., 1974; Rodriguez-Seda, 2008)
• Pedestrian bridges over major roadways (Benekohal et al., 2007; Guyton, 1983; Haines et al., 1974; Rodriguez-Seda, 2008)

traffic rules and regulations" is identified as an issue specific to college campuses (Dober, 2000, p. 139).

Several researchers have recommended actions to improve pedestrian safety on college campuses, which are summarized in Table 1 (Benekohal, Wang, & Medina, 2007; Guyton, 1983; Haines et al., 1974; Rodriguez-Seda, 2008; Zegeer, Seiderman, et al., 2002). These recommendations are consistent with the 2004 American Association of State Highway and Transportation Officials (AASHTO) *Guide for the Planning, Design, and Operations of Pedestrian Facilities* but are generic, and while they emphasize the need for short- and long-term transportation plans, they do not provide insights about the nature of pedestrian and bicycle crashes around campuses.

Very few studies have used spatial data to analyze transportation safety problems around college campuses (Schneider, Ryznar, & Khattak, 2004). A common shortfall of these studies is the limited transferability of insights to other campuses. A main barrier to the transferability of campus-related safety insights is the wide range in the availability and quality of data. This includes limited infrastructure and exposure data that are commonly different from typical city-level data, and lack of consistent crash data reporting among different campuses and police departments.

Two broad categories of factors discussed in the literature that are associated with pedestrian and bicycling crashes include traffic characteristics (traffic volume, speed, mode share, etc.) and built environment characteristics (road design, land uses, presence of sidewalks, medians, etc.). Outside the campus, studies have found that crashes are more likely to occur on major arterials (Walgren, 1998). Controlling for other factors, bicycle crashes tend to happen more on arterials lacking bicycle lanes, while the presence of bicycle lanes may reduce injury rates by up to 50% (Lott & Lott, 1976; Moritz, 1996, 1998; Rogers, 1997).

Major arterials concentrate many crashes because of their high levels of traffic. Researchers have found a significant relationship between traffic volume and number of crashes (Hess, Vernez Moudon, & Matlick, 2004; Jackson & Kochtitzky, 2001; Levine, Kim, & Nitz, 1995; Roberts, Norton, Jackson, Dunn, & Hassal, 1995). Indeed, pedestrian and cyclist exposure has been typically associated with collision risk. Nevertheless, lack of data on pedestrian and cyclist volumes often prohibits the inclusion of this important variable.

While about 40% of crashes occur at intersections, the majority happen in other locations such as midblock crosswalks, sidewalks, and parking lots (Campbell, Zegeer, Huang, & Cynecki, 2004). Studies have also explored the impact of marked sidewalks in uncontrolled locations on pedestrian crash rates, finding that on high-traffic (more than 12,000 vehicles per day), multilane streets, marked crosswalks are associated with higher crash rates than unmarked crosswalks (Zegeer, Stewart, et al., 2002).

Some studies have examined the effect on crashes of different built environment elements such as the number, type, and layout of streets; marking of crossroads; and land use mix. Examining hotspots of pedestrian crashes in Los Angeles, a study found that long blocks, multiple driveways, visual impairments for motorists and pedestrians, and relatively low levels of pedestrian lighting were related to higher incidence of crashes (Loukaitou-Sideris, Ligget, & Sung, 2007).

While there is a rich body of studies about pedestrian and bicycle safety in city settings, there are four major caveats for studies focusing on campus safety. First, the existing literature either includes a set of generic recommendations, or consists of case studies with non-generalizable recommendations. Second, the reported data available for campus crashes are not sufficient to conduct meaningful analyses of spatiotemporal patterns and crash factors.

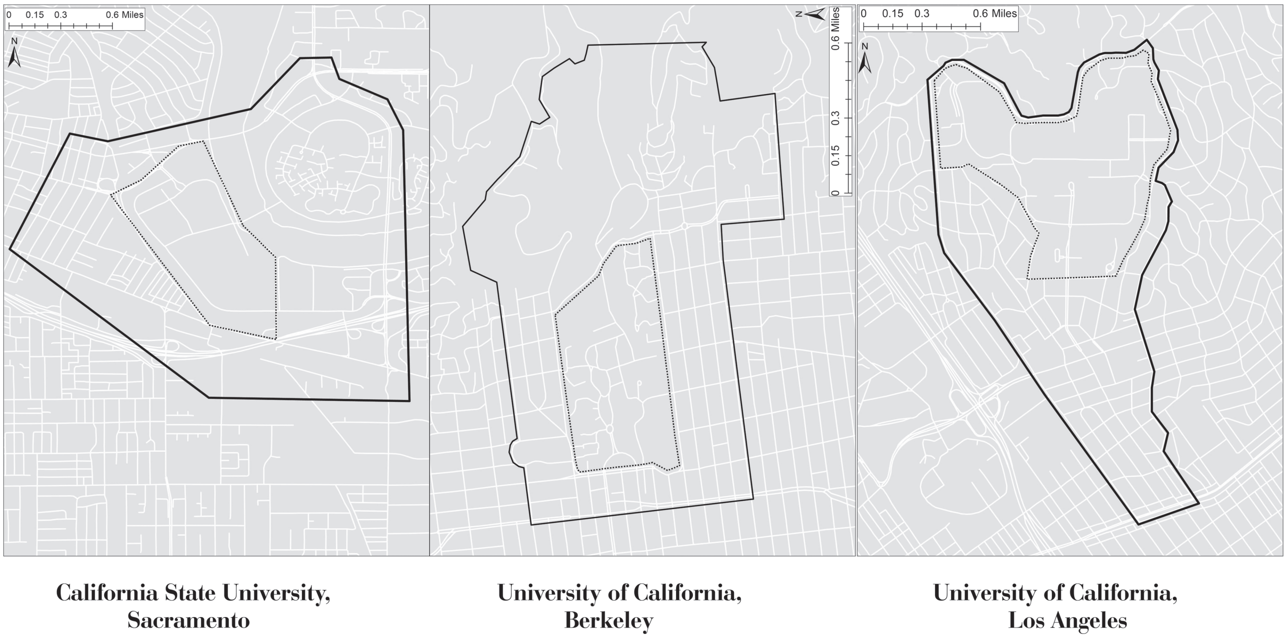


Figure 1. Boundaries associated with the study area of the three campuses.

Third, the lack of data results in a limited understanding of crash patterns, which inhibits the ability to develop adequate safety guidelines. Fourth, there is no examination of the interface between the campus and its surrounding area. Such interface, however, is important as pedestrians and bicyclists traverse from a highly non-motorized to an extremely multimodal environment. As many cities increasingly seek to add pedestrian plazas and bike paths to their urban form, they should take special notice of their interface with the surrounding areas. To respond to these issues, we now turn to our empirical study.

Pedestrian and Bicycle Crashes on Three Campuses

Context

The three campuses under study differ in size and form. UCB is a campus of 1,232 acres surrounded by a grid street network. It is close to a metro station, and a dense network of buses also serves the campus. UCLA extends over 419 acres and is also served by an extensive bus network. As an urban campus, it is surrounded by multiple arterials, one of which serves as a feeder for many trips leading to the main entrance on south campus. CSUS is a commuter campus of 300 acres that has a high share of campus trips made by private automobile. We define our three study areas to include the campuses as well as their immediate periphery, an area that extends for about one-quarter to one-half mile outside the campus boundaries, and which includes the major arterials and access points to each campus for pedestrians and cyclists (Figure 1). The reason for including the campus periphery was that some of the crashes occurring there likely involve campus population. In addition, campus peripheries tend to have much larger shares of pedestrians and cyclists than the rest of the city because significant numbers of students, faculty, and staff live near the campus.

The three campuses differ in population size, density, and volume of generated traffic. UCB has nearly 37,000 students and 16,000 faculty and staff. Overall, 75% of them walk, bike, or take transit to and from campus, which is reflected in the 12,000 weekday riders who enter the nearby Downtown Berkeley Bay Area Rapid Transit (BART) station (BART, 2010; Sugerman, 2011). UCLA has approximately 41,000 students and 26,000 faculty and staff. In 2011, pedestrian trips accounted for 19.1%, bicycling trips for 3.2%, and transit trips for 23.3% of all commutes to UCLA (UCLA Transportation, 2011). CSUS has approximately 29,000 students and 2,800 faculty and staff. The majority of the campus population (79%) commutes to the campus by private automobile. The campus is also accessed by bicyclists (6%), pedestrians (7%), and transit riders (8%) (Shafizadeh, 2013).

Figure 2 shows the variation in population density in and around the three campuses. The areas immediately surrounding UCLA and UCB have very high population densities (in some cases more than 50,000 people per square mile).[2] In contrast, most of the area surrounding the CSUS campus is not densely populated.

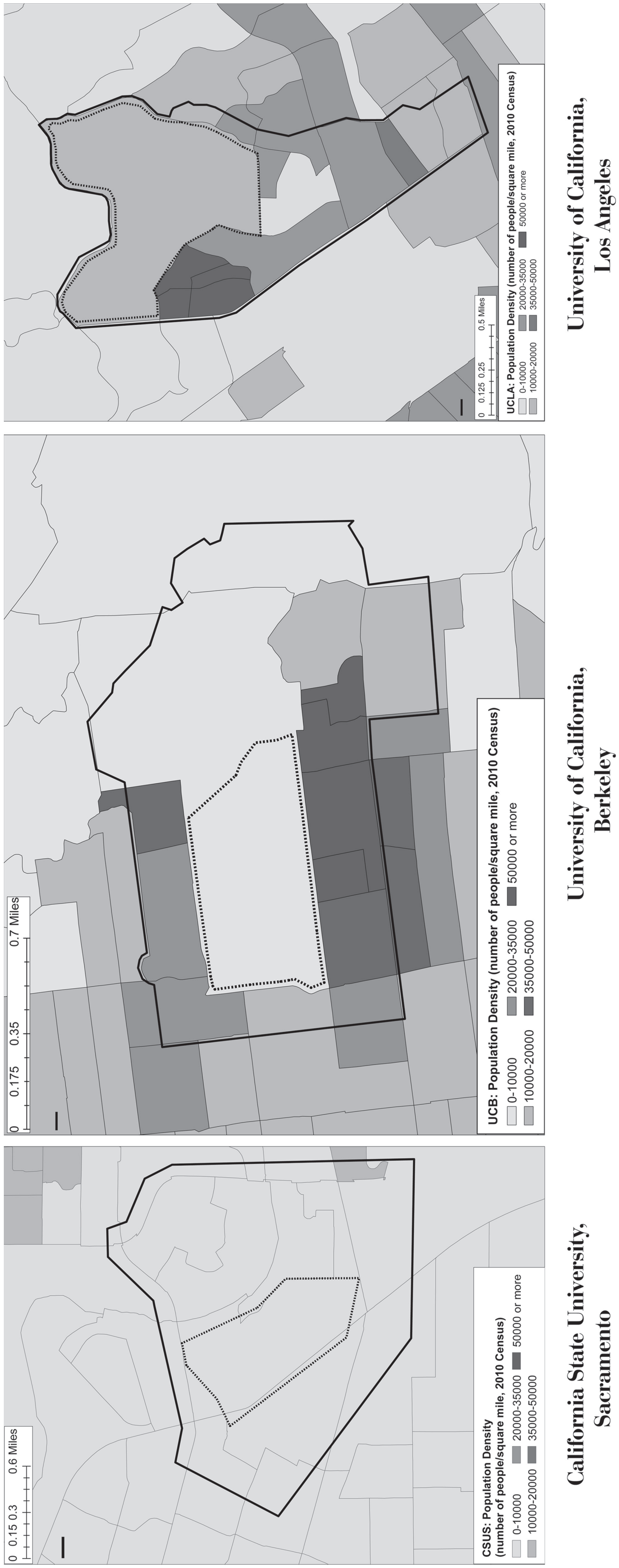


Figure 2. Population densities around the three campuses (based on U.S. Census, 2010).

Data Sources

We collected crash data from 2002 to 2011 from the Statewide Integrated Traffic Records System (SWITRS) and an online survey. SWITRS is a statewide repository of reported traffic collision data collected by the California Highway Patrol. It includes information about the date, time, location, and type of collision; age and gender of the driver and the victim(s); primary cause of collision; whether alcohol was involved; and the extent of injuries. SWITRS data provided useful information primarily for crashes on the campus peripheries. For information about campus crashes, we turned to the campus police units. However, we found that the number of reported crashes was extremely small. For example, the UCLA Police Department had on record only 15 crashes involving pedestrians or cyclists between 2009 and 2012.

To address underreporting and also get more qualitative information about crashes on the campuses and their peripheries, we developed and administered to each campus an online survey (see the Technical Appendix), facilitating self-reporting of crashes and perceived hazardous locations within the study areas. This was meant to uncover issues of both objective safety (measured by actual incidents) and subjective safety (indicated by people's perceptions). While research has shown only a weak positive relationship between objective and subjective safety (Menkehorst, van der Molen, & Miedema, 1990; Miedena, Menkehorst, & van der Molen, 1988), scholars have argued that subjective safety needs policy attention as it may lead to reduced mobility and accessibility (SWOV Institute for Road Safety Research, 2012). In addition, when incidents go underreported, it is difficult to assess objective safety.

Our survey inquired about the travel characteristics of respondents (modes and frequency of travel to and from campus), possible occurrence of accidents, and perceived hazardous locations (on or near the campus) for pedestrians and cyclists. If a respondent had experienced one or more crashes, they were further asked to use a mapping feature to indicate the precise location of each experienced crash. Followup questions asked respondents for details about the location and time of crashes, parties involved, contributing factors, crash severity, and whether crashes were reported to the police. Respondents could also provide a narrative description of the crash. Respondents used the same mapping process to indicate perceived hazardous locations.

Survey of the Three Campuses

We administered the online survey in February and March 2013 by distributing it through the Office of the Vice Chancellor for Research at UCLA and UCB and through the Office of the Provost at CSUS to all faculty, staff, and students of the three campuses who had university email accounts and had not asked to be excluded from email notifications (more than 95% of the campus population). We received back 5,167 completed surveys: 2,918 from UCLA, 1,879 from UCB, and 370 from CSUS. The majority of respondents was students (41.4%) and staff members (45.4%). The response rates—6.8% at UCLA, 5.0% at UCB, and only 1.0% at CSUS—were low, a trend that is typical of many campus surveys. While we targeted the full campus population, survey respondents were self-selected, and this may have led to overrepresentation of some groups and underrepresentation of others. We suspect that people who had experienced a crash or "near crash" may have been more motivated to respond. This, however, was not necessarily problematic, since we wanted to get information from those involved in crashes. Another possible survey shortfall was that respondents may have remembered more clearly the occurrence and details of recent crashes than earlier ones.

The 5,167 survey respondents reported experiencing a total of 662 crashes that involved either a bicycle or a pedestrian on or around the three campuses (Table 2). UCLA had significantly lower numbers of crashes per respondent (0.08 versus 0.17 and 0.20 at CSUS and UCB, respectively). Topography could be a factor, as UCB's hillier layout may be hazardous for bicyclists. Moreover, the drier climate in Los Angeles decreases the possibility for slippery surfaces and reduced visibility because of rain. That said, hillier terrains could discourage biking and walking, and the warmer climate could encourage it. More data are needed on the volumes of trips made by different travel modes to get a clearer explanation.

Less than 10% of the survey-reported crashes had been reported to the campus police. Respondents indicated that they failed to report crashes because they were minor (72.6%), or they did not believe that the police would do anything (25.8%). Indeed, only a small percentage of these crashes were characterized as very serious or serious (Table 3).[3]

Bicycling was the mode with the highest crash rate, with 23.1 crashes per 100 cyclist respondents (Table 4). Although walking accounted for more than two-fifths of reported crashes, only 5.5 out of every 100 pedestrian respondents had experienced a crash. Thus, the crash rate for bicycling was more than four times that of walking.

Temporal Distribution of Crashes

Significantly higher numbers of crashes occurred during the late fall and winter, likely because the weather is dry, and fewer classes are in session in the summer. The majority of crashes at all campuses took place in the

Table 2. Reported crashes involving pedestrians or cyclists.

Campus	SWITRS crashes (2002 to 2011)	Survey-reported crashes (% of total)	Survey-reported crashes per respondent
CSUS	131	63 (9.5%)	0.17
UCB	603	371 (56%)	0.20
UCLA	266	228 (34.4%)	0.08
Total	1000	662 (100.0%)	

Notes: CSUS = California State University, Sacramento; UCB = University of California, Berkeley; UCLA = University of California, Los Angeles; SWITRS = Statewide Integrated Traffic Records System.
Source: SWITRS.

morning and afternoon, when each campus has the highest numbers of people. Some differences were noted: At CSUS, most crashes involving pedestrians happened in the morning, whereas at UCB and UCLA most happened in the afternoon. UCLA experienced a significant share of bicycling crashes during the evening hours.

Location of Crashes

Table 5 shows the most common crash sites by campus and mode. In the high-density urban settings of UCLA and UCB, intersections were the most frequent locations for crashes experienced by pedestrians, while multiuse paths were the most frequent locations at CSUS. Since multiuse paths are only open to pedestrians and bicycles, most of the crashes there involved these two modes. Moreover, the second most frequent location for crashes involving pedestrians at all three campuses were sidewalks, indicating pedestrians were likely hit by cyclists riding on the sidewalk or by skateboarders, as some survey respondents indicated. Roadways and intersections were the two most frequent crash sites at UCB and UCLA, and the second and third most frequent sites for cycling crashes at CSUS. At CSUS, the highest percentage of cycling crashes occurred on multiuse paths (32.5%).

Cause of Crashes

While we had hypothesized that built environment attributes would play the most significant role in the causation of crashes, it was mostly behavioral factors that were brought up by the survey respondents. As Figure 3 shows, inattention was the most common behavioral factor contributing to crashes, reported by 56.6% of cyclists and 60.5% of pedestrians involved in crashes. For cyclists, excessive speed was a factor in 23.3% of crashes, while trying to avoid a cyclist, pedestrian, or vehicle was a factor in 22.1% of crashes. Almost half of the respondents involved in pedestrian crashes reported that the excessive speed of the cyclist or car that hit them or failure to yield to the right-of-way was a factor.

The most frequently reported environmental factors for bicycling crashes were narrow or obstructed bike lanes (33.0%) that forced bicyclists to enter space occupied by pedestrians, and cracked or uneven roadways (16.7%) that led to falls (Figure 4). In addition, respondents involved in cycling crashes cited cracked and uneven sidewalks (10.9%) and absence of sidewalks (11.2%). Narrow sidewalks were a factor for 6.9% of pedestrian-reported crashes, while cracked or uneven roadways contributed to 6.2% of such crashes. A significant percentage of respondents listed an array of additional environmental factors (listed as "other" in Figure 4), such as poorly designed or maintained bicycling infrastructure, poorly located bicycle facilities, lack of bike lanes or paths, poor signage, crowded pathways, road debris, construction blocking sidewalks, traffic, and lack of traffic signals. The variety of environmental conditions and factors reported suggests that these can be context-specific and may involve both fixed design characteristics (e.g., cycling facilities or signage) as well as conditions that vary by time or location (e.g., traffic or

Table 3. Injury severity of crashes (percentage of reported crashes).

Injury severity	Biking	Walking
Very serious	2.0%	0.0%
Serious	8.3%	2.5%
Not serious	47.4%	17.8%
Minor	10.9%	22.1%
No injuries, property damage	3.2%	1.4%
No injuries, no property damage	28.2%	56.2%
Total	100.0%	100.0%

Table 4. All crashes by mode.

Respondent mode type	Crashes	Percentage of total	Per 100 respondents (by mode)
Biking	348	52.6%	23.1
Walking	276	41.7%	5.5
Driving	38	5.7%	0.9
Total	662	100.0%	6.1

Table 5. Top three locations of crashes.

	CSUS		UCB		UCLA	
	Biking	**Walking**	**Biking**	**Walking**	**Biking**	**Walking**
1	Multiuse path 32.5%	Multiuse path 47.6%	Roadway 35.3%	Intersection 36.6%	Roadway 42.1%	Intersection 40.9%
2	Roadway 27.5%	Sidewalk 28.6%	Intersection 17.6%	Sidewalk 23.4%	Intersection 19.8%	Sidewalk 34.1%
3	Intersection 17.5%	Midblock crossing 9.5%	Multiuse path 16.0%	Multiuse path 23.4%	Bike lane 11.6%	Driveway 5.7%

Notes: CSUS = California State University, Sacramento; UCB = University of California, Berkeley; UCLA = University of California, Los Angeles.

construction). Notable were concerns about lighting voiced by bicyclists on the three campuses: A significant portion of bike crashes took place during the evening.

Hazardous Locations

The survey asked respondents to identify sites they considered particularly hazardous in terms of traffic safety. Using a Google Maps interface, respondents indicated these hazardous locations and the factors that made them dangerous. A surprisingly high number of locations were reported as hazardous: 2,537 at UCLA, 1,819 at UCB, and 481 at CSUS. Hazardous locations were highly dispersed, which may be associated with the inherent variation between locations or because of possible inaccuracies in the reporting sites. As a result, it was helpful to associate them and the reported crash locations to reference locations, such as the closest intersections or midblock crossings, and identify hotspots (locations with high concentration of crashes).

Hotspots of Crashes and Hazardous Locations

To suggest improvements to the transportation infrastructure around campus, it is essential to identify the

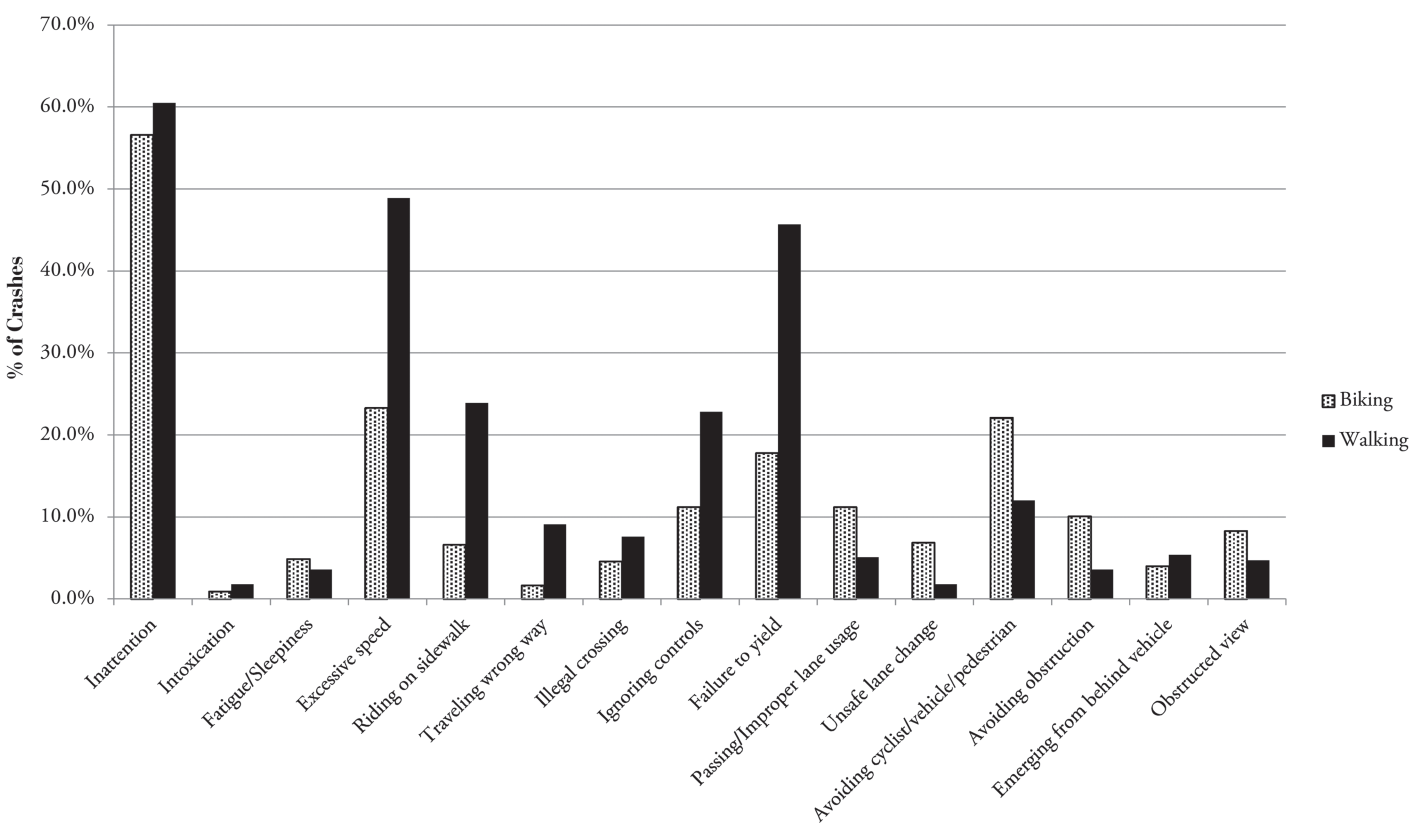


Figure 3. Behavioral causes of crashes.

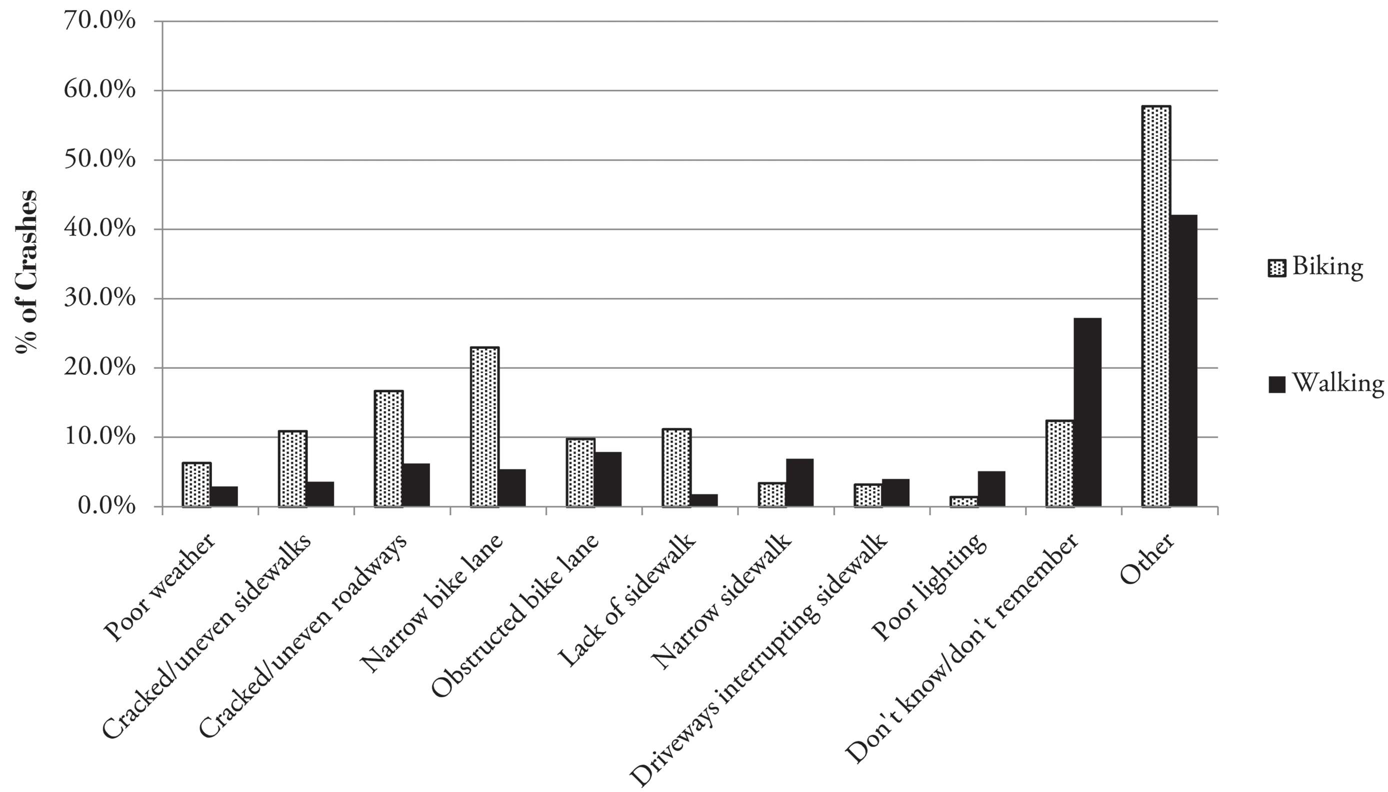


Figure 4. Environmental causes of crashes.

locations where pedestrians and bicyclists are most at risk. For this study, we first identified all intersections, midblock crossings, and other heavily traveled locations on campus as candidate hotspot locations. Using the crash locations and the candidate hotspot locations as inputs, traditional clustering algorithms aggregated crashes to the nearby candidate hotspot locations. If a crash was close to two or more locations of interest, an inverse distance-based weight was used to allocate the crash among these locations.[4] We defined "close" as the maximum influence distance, equal to 0.05 mile. By summing the weights from all the crashes, we identified the locations with the highest concentration of crashes. The hotspot analysis was done separately for each mode type (pedestrian or bike collision), data source (SWITRS, survey-reported crashes, survey-reported hazardous locations), and campus. The results shown in Figures 5, 6, and 7 highlight the top 15 hotspot locations of reported crashes and hazardous locations for each mode (pedestrian, bicycle) and data set combination (SWITRS and survey).

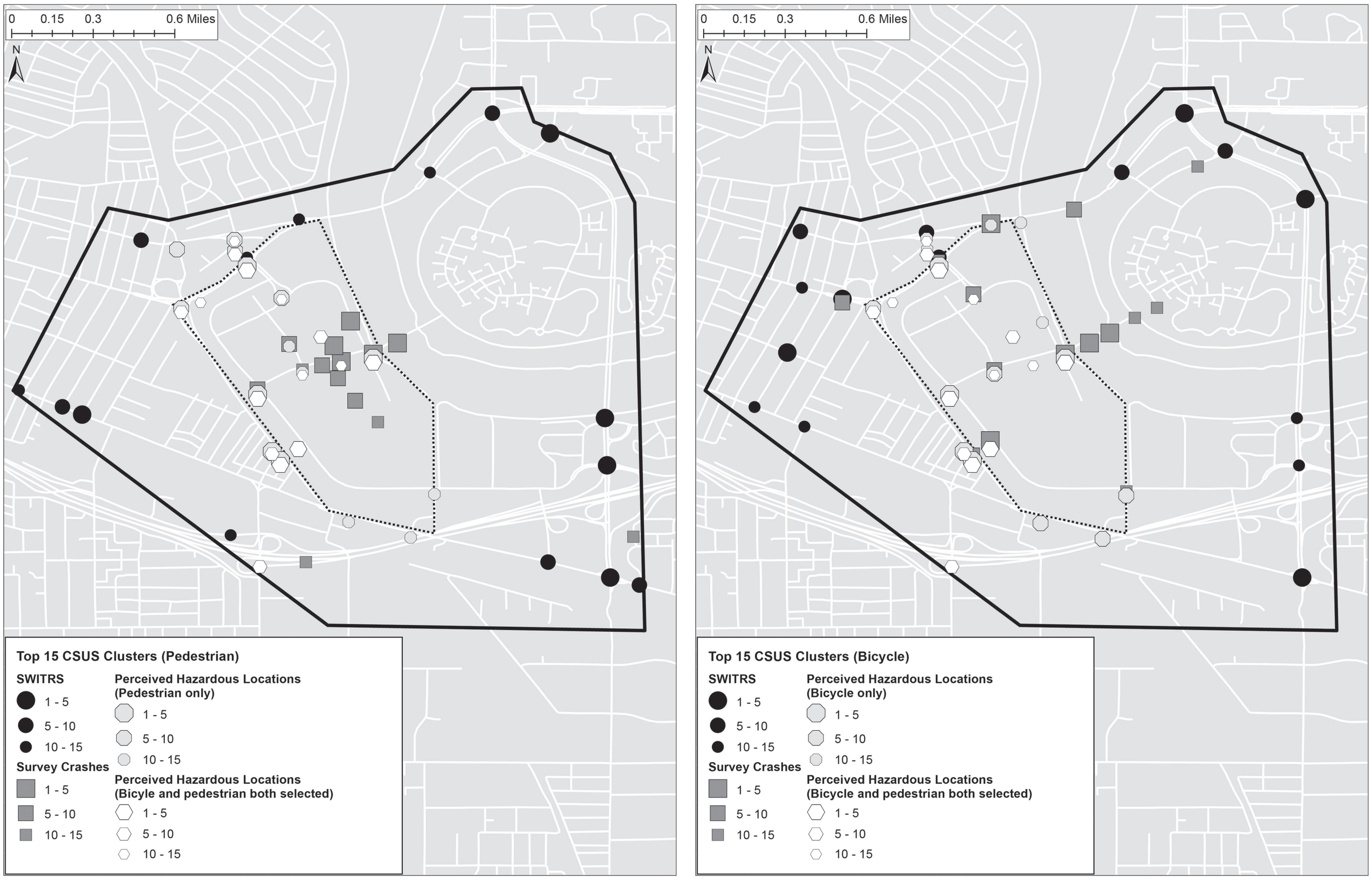
A visual inspection of Figures 5, 6, and 7 shows several similar patterns across the three campuses. First, as further substantiated in Table 6, the crashes as well as the resulting hotspots obtained from SWITRS lie further away from the campus compared with the survey-reported hotspots, which tend to be closer to or inside the campus. The reason for this is the underrepresentation of campus crashes in the SWITRS database, which makes clear the inadequacy of this public data set to capture many crashes occurring within campus boundaries.

Second, certain corridor effects can be observed in each study area, with hotspots aligning along major arterials (e.g., Folsom Boulevard and Howe Avenue in CSUS; Bancroft and Shattuck Avenues in UCB; and Westwood Boulevard and Wilshire Avenue in UCLA). In particular, the UCB campus had a significant number of crashes (15% to 20% depending on the data source) taking place within 0.02 mile from the campus boundary. The boundary effect persisted as far as 0.05 mile from the campus.

Third, the top four or five hotspots of perceived hazardous locations at each campus overlapped with the top crash hotspots reported in the survey. Last, hotspots of bike crashes and perceived hazardous locations tended to be more spread out than hotspots of pedestrian crashes and perceived hazardous locations, likely because bikes are used for longer commutes.

Understanding the Campus Danger Zones

Hotspot analysis is useful to identify the most at-risk locations in and around campus. However, to analyze the pedestrian and bicycle safety at a system level, it is important



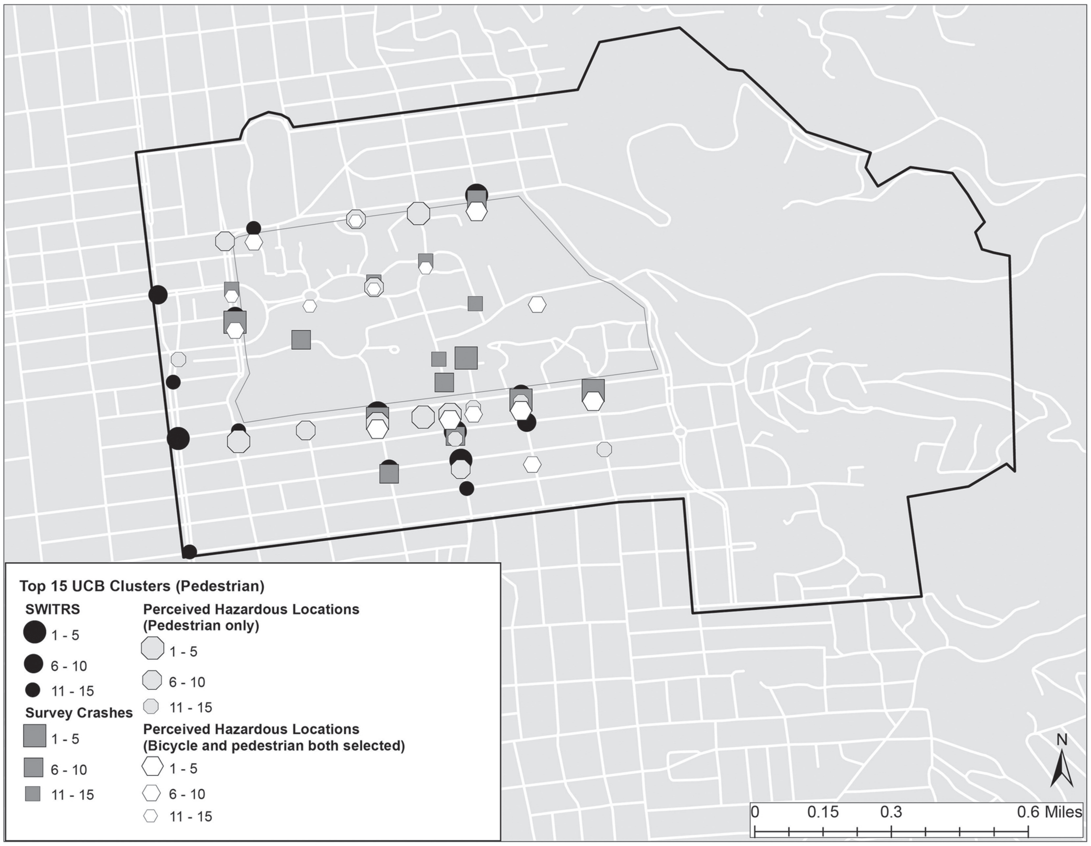
Pedestrian **Bicycle**

Figure 5. California State University, Sacramento (CSUS) hotspots.

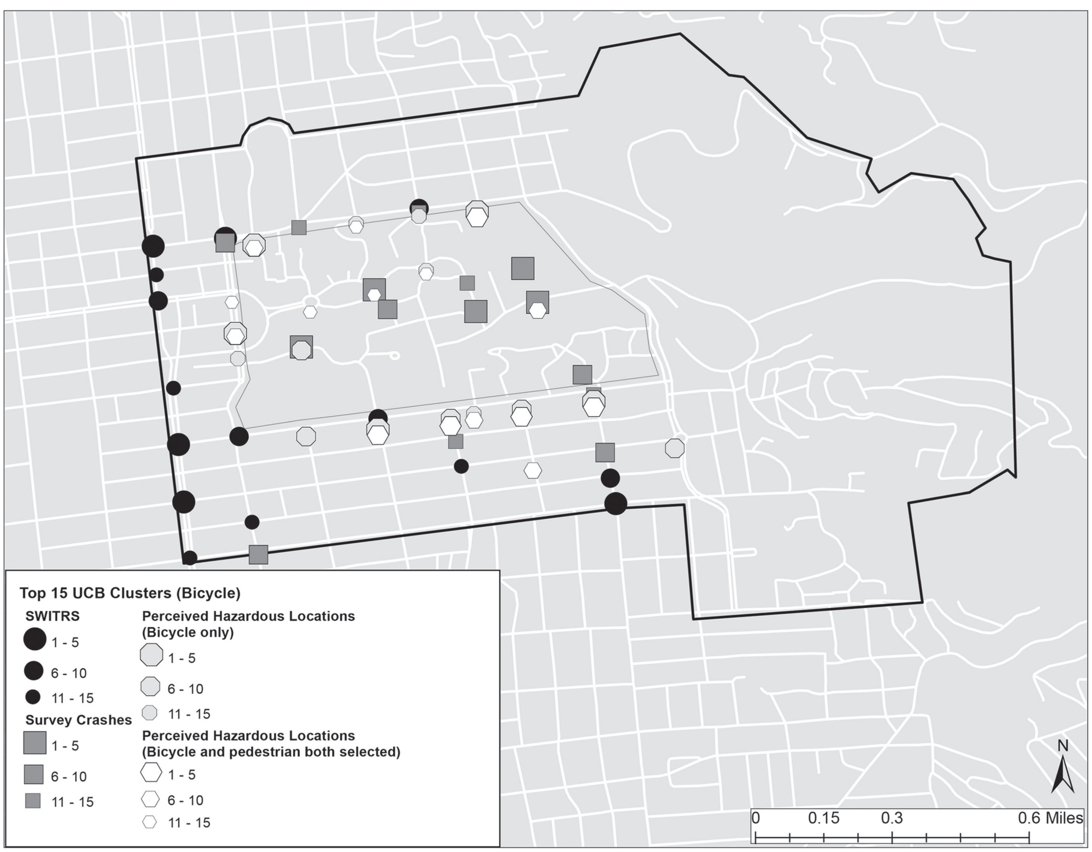
to recognize that a campus consists of different types of settings as well as varying levels of multimodal interactions. In addition, the use of more general performance metrics to assess campus safety can help transfer the lessons to other campuses. Hence, we drew from our findings of crash locations to develop a taxonomy of *campus danger zones*. We derived the categories of the taxonomy after visiting the top 15 pedestrian and 15 bicycle hotspots of crashes in each campus and collecting qualitative information about their location, surrounding built environment, land uses, social activity, and type and volume of pedestrian and vehicular traffic. We noted that all top hotspots belonged to one of the following categories:

a) *Campus activity hubs* are dominant trip attractors or generators located on the campus or its periphery. Such locations include libraries, eateries, plazas, major parking facilities, and dormitories.
b) *Campus access hubs* are located along the campus boundary and are predominantly used to enter or exit the campus. Examples include campus entrances, bridges, and pedestrian overpasses or underpasses.
c) *Through-traffic hubs* are located within the campus or along its periphery and used by motorized traffic to get around or through the campus for trips that are not always associated with campus activities. Examples include intersections associated with major arterials that run through or around the campus.

The summary statistics associated with each type of campus danger zone are shown in Table 7.[5] Table 7 shows that campus activity hubs are dominated by interactions between pedestrians and bicyclists. Because they are located within the campus boundaries, the volume and speed of motorized traffic around such hubs are typically low. Many collisions result from the sharing of space between pedestrians and bicyclists, which suggests that infrastructure-related concerns such as obstructed sidewalks or bike lanes may be important. In addition, inattention and excessive speeding were also cited as concerns. Because the majority of incidents at campus activity hubs involved bicyclists and pedestrians, only 6% of the crashes resulted in serious injuries, while 43% involved non-serious injury.

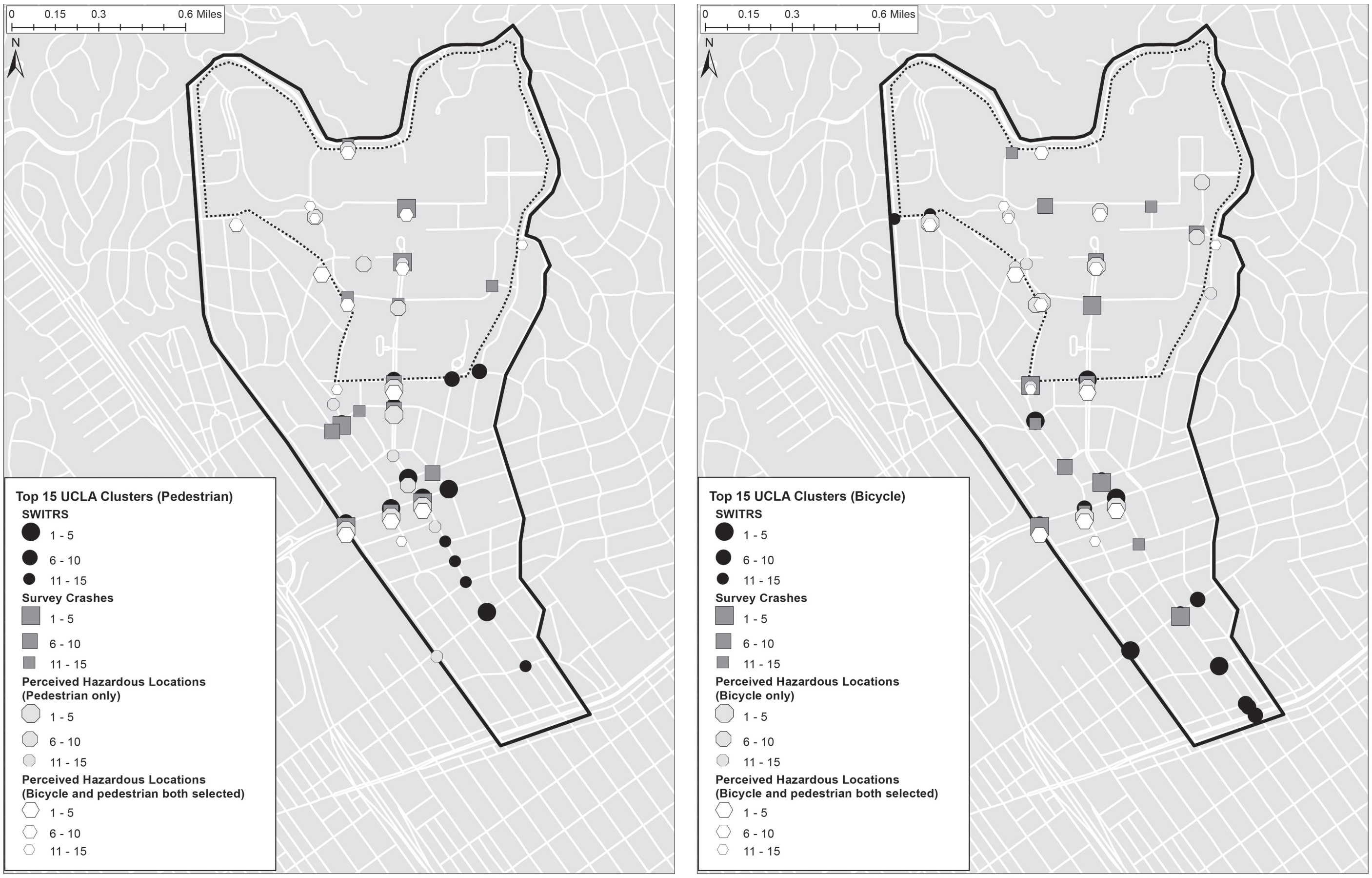


Pedestrian



Bicycle

Figure 6. University of California, Berkeley (UCB) hotspots.



Pedestrian **Bicycle**

Figure 7. University of California, Los Angeles (UCLA) hotspots.

Campus access hubs are characterized by large volumes of motorized and non-motorized traffic, which concentrate crashes involving different modes. Collisions involving a combination of non-motorized modes, vehicles, and stationary objects cumulatively represented more than 90% of crashes here. Dominant factors associated with crashes at campus access hubs include inattention, excessive speeding, and failure to yield. Compared with other danger zones, the campus access hubs have a slightly higher representation of evening/nighttime crashes (23%), which is perhaps because these sites are the primary locations for exiting the campus.

The through-traffic hubs are heavily dominated by conflicts between non-motorized and motorized modes (61%). As a result, issues such as failure to yield and ignoring traffic controls were the most common factors responsible for

Table 6. Distribution of crashes inside and outside campus area for the different data types.

	CSUS		UCB		UCLA	
Crash type	Inside campus	Outside campus	Inside campus	Outside campus	Inside campus	Outside campus
SWITRS (pedestrian)	7.69%	92.31%	19.49%	80.51%	12.69%	87.31%
SWITRS (bike)	11.96%	88.04%	17.18%	82.82%	15.94%	84.06%
Survey crashes (pedestrian)	85.71%	14.29%	66.67%	33.33%	55.68%	44.32%
Survey crashes (bike)	56.41%	43.59%	60.57%	39.43%	45.30%	54.70%
Perceived hazardous locations (pedestrian)	90.91%	9.09%	60.14%	39.86%	67.50%	32.50%
Perceived hazardous locations (bike)	73.83%	26.17%	44.71%	55.29%	36.06%	63.94%

Notes: CSUS = California State University, Sacramento; UCB = University of California, Berkeley; UCLA = University of California, Los Angeles; SWITRS = Statewide Integrated Traffic Records System.

Table 7. Attributes of crashes at different campus danger zones.

	Campus danger zones		
Attributes	**Campus activity hubs**	**Campus access hubs**	**Through-traffic hubs**
Crashes at hotspots	107	73	89
Crash types	53% ped with bike 11% auto with bike or ped 33% bike or ped with object 6% bike with bike	38% ped with bike 29% car with bike or ped 35% bike or ped with object 9% bike with bike	16% ped with bike 61% auto with bike or ped 24% bike or ped with object 5% bike with bike
Crash severity	51% no injury 43% non-serious injury 6% serious injuries	48% no injury 49% non-serious injury 3% serious injuries	36% no injury 53% non-serious injuries 11% serious injuries
Time of crash	76% during the day 18% during evening or night	69% during the day 23% during evening or night	74% during the day 20% during evening or night
Behavioral factors	49% inattention 35% excessive speed 20% failure to yield 20% trying to avoid pedestrian/bike/vehicles	51% inattention 33% excessive speed 27% failure to yield	62% inattention 48% failure to yield 29% ignoring traffic controls
Environmental factors	16% obstructed bike lane 17% obstructed sidewalk	18% cracked pavement 16% obstructed bike lane	16% obstructed bike lane 14% cracked pavement

the survey-reported crashes. Crashes at through-traffic hubs had the highest levels of injury severity among all three campus danger zones, with 11% serious injuries and 53% non-serious injuries.

The findings from the survey and the analysis of the characteristics of hotspots and danger zones help us to outline a series of recommendations for safer campuses.

Recommendations for Safer Campuses

No singular design or policy action can address all the behavioral and environmental factors that contribute to crashes on or near campuses. In addition to the more general recommendations suggested by other studies (Table 1), such as the establishment of short- and long-term campus master plans for walking and biking, the banning of automobiles from inner-campus streets, the installation of attention-grabbing traffic signage on campus, the creation of bike networks, etc., we suggest that campuses can take additional actions for safer walking and biking.

Safety Audit for the Identification of Hotspots and Danger Zones

We noticed a significant underreporting of crashes at all three campuses. This leads to the inadequacy of policy and design responses and an erroneous sense of objective safety. Campus resources for infrastructure improvements that enhance the safety of biking and walking are not limitless. To design effective improvements and master plans, campuses need to know and tackle the particular locations where crashes are most concentrated. For this reason, campus administrations should consider conducting a web-based survey every four to five years (coinciding with the turnover of the undergraduate student population), similar to the one used in this study.[6] Using such a timescale can also reveal whether these subjective data sources reproduce the same set of hotspots over time. This survey can serve as a safety audit to identify the major hotspots for crashes and hazardous locations, thus addressing issues of objective and subjective safety. Over a period of time, such a repository of crowd-sourced data can be routinely compared with the public crash databases to identify avenues for data fusion. Also, universities can consider the creation of an interactive website where people can report the campus location and characteristics of crashes they were involved in.

Improvements for Danger Zones

The concept of danger zones identified in this study provides the necessary level of aggregation to understand the risk to pedestrians and bicyclists on and around the campus. The three distinct types of locations described in the taxonomy are common to most campuses. As a result, the taxonomy provides a standardized framework for periodically assessing and enhancing pedestrian and bicycle safety on campus. Specific policies and improvements to the built environment at danger zones could enhance pedestrian and bicycling safety. In addition to providing some general recommendations for the different danger zones below, Tables 8, 9, and 10 profile specific examples from our case studies pertaining to each different category. These case studies combine the inputs from the survey with onsite investigation to identify potential improvements.

More than half of the crashes at campus activity hubs were between bicyclists and pedestrians (Table 7). As the survey shows, many of these crashes take place because bicycles and pedestrians share common paths or because the former intrude into the latter's space when they encounter obstructed or nonexistent bike lanes. Therefore, campus planners should assess the feasibility of reorganizing non-motorized traffic near major activity hubs. Some of the potential improvements include channeling bike traffic through well-defined bike-only paths near activity hubs and converting pedestrian-heavy paths into pedestrian-only zones (as shown in Table 8).

Campuses should give particular attention to their major entry points, because it is there where different modes interface. It is important that the traffic control strategies deployed at campus access hubs prioritize the smooth passage of pedestrians and bicyclists, who are the most vulnerable travelers. Traffic signals at intersections should give generous time for pedestrians on crosswalks leading to the campus, and traffic-calming devices (e.g., vertical or horizontal deflections, medians) should be considered. Good lighting and signage are also important at all access points. Moreover, campus bicycle plans should be cognizant of the origins and destinations of pedestrian and bicycle commuters so that pedestrian-only and bicycle-only access points are appropriately selected around the campus. As an example, Table 9 shows the issues at a common access point for bicyclists and pedestrians in CSUS and the need for separation of modes and well-marked signage at such a location.

This study shows that the most dangerous locations (in terms of accident severity) are on the campus boundaries, where high volumes of motorized traffic at through-traffic hubs present major concerns for pedestrian and bicycle safety. For this reason, vehicular traffic speeds on all arteries surrounding the campuses should be reduced. Assuming that through-traffic hubs are not meant to be the primary access or egress points for the campus, it would be helpful to also discourage pedestrian and bicyclists from using them by diverting non-motorized traffic to the campus access hubs through signage. Also, the visibility of pedestrians and

Table 8. Campus activity hub case study: University of California, Los Angeles (UCLA).

Location	Description	Documented concerns	Proposed/potential solutions
Bruin Plaza (UCLA)	• Bruin Plaza lies at the intersection of the Student Activity Center, Wooden Center, and Ackerman Union. • In 2009, the university set up a dismount zone in Bruin Plaza, which requires bikes, skateboards, and scooters to walk their wheels.	"Cyclists and skateboarders don't dismount." "People on skateboarders traveling too fast."	• In January 2013, the UC Police Department issued a statement that they would start issuing more tickets to all riders and skateboarders who violate the dismount zone rules (http://goo.gl/x06z0w). • Other options include rerouting the bicycle traffic along alternate routes such as Strathmore Tunnel or Charles E. Young Drive.

– Pedestrian hotspots: Ranked #1 (survey crashes), #6 (perceived hazardous locations to pedestrian only)
– Bicycle hotspots: Ranked #6 (perceived hazardous locations to cyclists only)
– Ranked #10 among the hotspots based on locations perceived to be hazardous to both pedestrians and cyclists

Bruin Plaza

Dismount zone signage at Bruin Plaza

Table 9. Campus access hub case study: California State University, Sacramento (CSUS).

Location	Description	Documented concerns	Proposed/potential solutions
Guy West Bridge ramp at Jed Smith Drive (CSUS)	• Jed Smith Drive is a three-legged, unsignalized intersection with Jed Smith Drive as the through road and the Guy West Bridge ramp as the third leg. • Jed Smith Drive is only open to bicycles, pedestrians, and university service vehicles. • The Guy West Bridge links the east side of CSUS to American River Bike Trail, and is also the primary access route between the campus and the nearby off-campus residential neighborhoods, such as Campus Commons. • The bridge has a ramp that curves and descends onto the campus next to a large bicycle parking compound.	"Cyclists coming down off the path via the ramp travel too fast and ride on the sidewalks instead of using the roadway."	• As there is sufficient physical space available at this location, a wide pedestrian walkway along the west side of Jed Smith Drive can be separated from a dedicated, painted bicycle lane on the east side of Jed Smith Drive for access to either the bicycle corral or the Guy West Bridge. • To encourage bicyclists descending from the bridge ramp to slow down and yield to bicyclists emerging from the bicycle corral, some yield marking can be used. Similar interventions have also been taken in Portland (OR), where grade-separated bicycle paths meet at-grade bicycle paths (http://goo.gl/qsDmCg).

– Pedestrian hotspots: Ranked #1 (survey crashes), #5 (perceived hazardous locations to pedestrians only)
– Bicycle hotspots: Ranked #1 (survey crashes), #4 (perceived hazardous locations to cyclists only)
– Ranked #2 among the hotspots based on locations perceived to be hazardous to both pedestrians and cyclists

Southbound Jed Smith Drive

Bicycle parking compound, concrete pillars, and Guy West Bridge ramp in background

bicyclists at these crossings can be improved through lighting, better signage, limited curbside parking, and, if necessary, automated/actuated pedestrian detection systems, such as flashing beacons, to alert through traffic. Last, arterials bordering or leading to the campus that are heavily used by cyclists should have continuous bike lanes. While universities do not control the roadways outside the campus boundaries, campus representatives can work with city departments of transportation to retrofit campus-adjacent major arterials with bicycle-friendly facilities. Table 10 provides a case study where UCB is coordinating with city officials to make design improvements to a dangerous through-traffic hub.

Improvements for Multiuse Paths

This study also shows that a significant number of pedestrian–bicycle crashes took place along multiuse paths. Unlike the campus danger zones, multiuse paths are difficult to isolate as point locations/hotspots. Instead, they are usually dispersed around the entire campus area, acting as corridors for transporting pedestrians and bicyclists from one part of the campus to another. To be safe for all users, such paths should provide adequate width and appropriate pavements for everyone, have separate lanes for bicyclists and pedestrians, and signs that clearly state the rules of travel (Federal Highway Administration, 2014).

Conclusion

It is clear that the coexistence and intermingling of motorized and non-motorized modes on and around university campuses create opportunities for crashes. For this reason, campuses provide unique laboratories for planners wishing to understand and respond to the challenges of multimodal environments. These crashes are differentially allocated spatially and temporally. As we see in this study, most of the injuries occurring within the campus boundaries are not serious because many campus areas are not open to automobiles and campus speed limits are lower. Nevertheless, crashes between pedestrians, bicyclists, and skateboarders are common. In addition, campus vicinities often have high levels of motorized

Table 10. Through-traffic hub case study: University of California, Berkeley (UCB).

Location	Description	Documented concerns	Proposed/potential solutions
Addison Street at Oxford Street (UCB)	• Oxford Street is a three-legged, unsignalized intersection with no stop signs along the through street (Oxford Street) and a stop sign for the third leg (Addison Street). • Oxford Street is a major north–south thoroughfare with two travel lanes, a bicycle lane, and parking lane in each direction. • Addison Street is a much smaller, two-way street with a travel lane and a parking lane in each direction. • The eastern edge of the intersection is a sidewalk adjoining the campus boundary. This sidewalk is also connected to a pedestrian path that leads to the western entrance of the campus.	"Uncontrolled crosswalk across two lanes of traffic each way (crossing Oxford St.). Cars seldom stop: those in the second lane less so." "While three lanes of traffic stopped for me, a van decided to jump the fourth."	• The 2005 UC Berkeley Long Range Development Plan Environmental Impact Report recommends the following: *The University will work with the City of Berkeley to design and, on a fair share basis, install a signal at the Addison Street/Oxford Street intersection, and provide the necessary provisions for coordination with adjacent signals along Oxford Street (http://goo.gl/zCfFF3).* • The city is also planning to remove ten street parking spots along Oxford Street near this intersection, so as to expand the sidewalk and add a bulbout. These efforts are also likely to improve the visibility of pedestrians at this location (http://goo.gl/A8ZuxP).

– Pedestrian hotspots: Ranked #10 (SWITRS), #5 (survey crashes), #2 (perceived hazardous locations by pedestrians)
– Ranked #2 among the hotspots based on locations perceived to be hazardous to both pedestrians and cyclists

Addison Street

Southbound lanes of Oxford Street

through-traffic as well as pedestrians and cyclists commuting to and from the campus. In such areas, the potential for more severe crashes and injuries is higher.

The potential for crashes on the campus and its adjacent area is higher at the campus danger zones, and a careful study of these locations should lead to design, planning, engineering, and policy solutions tailored to each campus environment. We believe that similar danger zones can also be found on and around large high school campuses, where there is a mixture of different motorized and non-motorized modes. However, the traffic peak hours for high schools are more concentrated (at the beginning and the end of the school day) than those of universities. Similarly, multiuse paths and bicycle boulevards are increasingly becoming a part of the urban environment, and it is likely that an evaluation of their safety concerns may reveal characteristics that are very similar to those observed in this study. Last, although built environment characteristics (such as absence of bike lanes or sidewalks, cracked or uneven pavements, etc.) can play a role in the causation of crashes, our survey respondents also strongly complained about behavioral characteristics such as inattention and excessive speeding.

In the last decade, a number of university campuses have touted sustainability as a major goal of campus planning. Similarly, walkability and bikeability represent prominent concerns of many contemporary urban design plans (Linovski & Loukaitou-Sideris, 2013), and many cities have expanded their efforts to create "complete streets" and promote alternative modes of transportation. Encouraging and supporting travel to campus by modes other than the private automobile can play a major role in achieving a "greener" and more sustainable university campus and also reducing emissions in cities.

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Notes

1. In 2013, there were 4,726 degree-granting postsecondary institutions in the United States, which corresponds to approximately 24.2 million students, faculty, and staff (Snyder & Dillow, 2013).

2. For comparison, we note that in 2010, the Los Angeles–Long Beach–Anaheim metropolitan area had an average population density of 6,999 people per square mile; the city of Sacramento had an average density of 4,660 people per square mile; and the city of Berkeley had an average density of 10,752 people per square mile (U.S. Census, 2010).

3. We used the following definitions to characterize injuries: very serious (overnight hospital stay); serious (hospital visit, not overnight); not serious (scrapes and bruises); minor (no visible scrapes or bruises); no injuries, property damage only; no injuries, no property damage.

4. To further explain the weight-based allocation of a crash, consider the following example: if a crash is located 0.01 and 0.03 mile away from two locations A and B, then location A is attributed three-fourths (1/0.01/(1/0.01 + 1/0.03)) of the crash, and location B is allocated one-fourth of the crash. At the same time, in the absence of a detailed collision report, the crash allocation provides a nonzero probability to any other intersection within the influence distance to also be associated with the crash. Any location further than the maximum influence distance from a crash is automatically given a zero weight for that particular crash.

5. These results were computed through a weighted average of the summary statistics of all the hotspots associated with each campus danger zone, wherein the weight corresponded to the number of crashes associated with a hotspot.

6. Universities may also consider administering a shorter version of the survey at more frequent intervals.

References

Balsas, C. J. L. (2003). Sustainable transportation planning on college campuses. *Transport Policy*, *10*(1), 35–49. doi:10.1016/S0967-070X(02)00028-8

Bay Area Rapid Transit. (2010). *BART station profile study*. San Francisco, CA: Author.

Benekohal, R. F., Wang, M., & Medina, J. C. (2007). *Crosswalk signing and marking effects on conflicts and pedestrian safety in UIUC campus: Traffic Operations Laboratory* (Report). Department of Civil and Environmental Engineering, University of Illinois at Urbana-Champaign.

Campbell B. J., Zegeer, C., Huang, H., & Cynecki, M. (2004). *A review of pedestrian safety research in the United States and abroad* (FHWARD-03-042). McLean, VA: Federal Highway Administration.

Dobbs, G. (2009). *Pedestrian and bicycle safety on a college campus: Crash and conflict analyses with recommended design alternatives for Clemson University* (Unpublished master's thesis). Clemson University, Clemson, SC. Retrieved from http://tigerprints.clemson.edu/all_theses/552

Dober, R. P. (2000). *Campus landscape: Functions, forms, features*. Hoboken, NJ: John Wiley & Sons.

Federal Highway Administration. (2014). *Designing sidewalks and trails for access. Part II: Best practices design guideline.* Retrieved from http://www.fhwa.dot.gov/environment/bicycle_pedestrian/publications/sidewalk2/sidewalks214.cfm

Grembek, O., & Ragland, D. R. (2012). *The relative vulnerability matrix for evaluating multimodal traffic safety* (Working Paper). Berkeley, CA: UC Berkeley Safe TREC.

Guyton, J. W. (1983). Campus traffic and parking problems and some solutions. *Transportation and Land Use Planning. Transportation Research Record, 931,* 80–82. Retrieved from http://trid.trb.org

Haines, G., Kochevar, R., & Surti, V. H. (1974). Analysis of campus traffic problems. *Pedestrian Programs and Motorist Services, Transportation Research Record*, *498,* 1–12. Retrieved from http://trid.trb.org

Hess, P. M., Vernez Moudon, A. & Matlick, J. M. (2004). Pedestrian safety and transit corridors. *Journal of Public Transportation, 7*(2), 73–93. Retrieved from http://www.nctr.usf.edu/wp-content/uploads/2010/03/JPT-7-2.pdf

Jackson, R., & Kochtitzky, C. (2001). *Creating a healthy environment.* Sprawl Watch Clearinghouse Monograph, Washington, DC. Retrieved from http://www.sprawlwatch.org

Lantz, A. (2010). *Cycling in Los Angeles: Findings from a survey of Los Angeles cyclists* (Unpublished master's thesis). University of California, Los Angeles.

Levine, N., Kim, K., & Nitz, L. (1995). Spatial analysis of Honolulu motor vehicle crashes: I. Spatial patterns. *Accident Analysis & Prevention*, *27*(5), 663–674. doi:10.1016/0001-4575(95)00017-T

Linovski, O., & Loukaitou-Sideris, A. (2013). Evolution of urban design plans in the United States and Canada: What do the plans tell us about urban design practice. *Journal of Planning Education and Research*, *33*(1), 66–82. doi:10.1177/0739456X12454174

Los Angeles County Metropolitan Transportation Authority. (2004). *Enhanced public outreach project for Metro's bicycle transportation strategic plan.* Retrieved from www.metro.net/projects_studies/bikeway_planning/images/bicycle_final_report.pdf

Lott, D. F., & Lott, D.Y. (1976). Effect of bike lanes on ten classes of bicycle-automobile accidents in Davis, CA. *Journal of Safety Research, 8*(4), 171–179. Retrieved from http://www.safetylit.org/citations/index.php?fuseaction=citations.viewdetails&citationIds%5B%5D=citjournalarticle_25647_19

Loukaitou-Sideris, A., Ligget, R., & Sung, H. G. (2007). Death on the crosswalk: A study of pedestrian-automobile collsions in LA. *Journal of Planning Education and Research, 26*(3), 338–351. doi:10.1177/0739456X06297008

Menkehorst, H., van der Molen, H. H., & Miedema, B. (1990). The measurement of subjective experiencing of traffic safety in residential areas. In *Living and moving in cities: Actes du Congrès, Paris, 29–31 January 1990* (pp. 317–322). Bagneux, France: Centre D'Études des Transports Urbains.

Miedema, B., Menkehorst, H. & van der Molen, H. H. (1988). The subjective experience of traffic safety, consequences for design. In J. A. Rothengatter & R. A. de Bruin (Eds.), *Road user behavior: Theory and research* (pp. 435–442). Assen, The Netherlands: Van Gorcum.

Moritz, W. E. (1996). Survey of North American bicycle commuters: Design and aggregate results. *Transportation Research Record, 1578*, 91–101. doi:10.3141/1578-12

Moritz, W. E. (1998). Adult bicyclists in the U.S.: Characteristics and riding experience in 1996. *Transportation Research Record, 1636*, 1–7. doi:10.3141/1636-01

Reynolds, C., Harris, M. A., Teschke, K., Cripton, P. A., & Winters, M. (2009). The impact of transportation infrastructure on bicycling injuries and crashes: A review of the literature. *Environmental Health, 8*(47), 1–19. doi:10.1136/bmj.310.6972.91

Roberts, I., Norton, R., Jackson, R. Dunn, R., & Hassall, I. (1995). Effect of environmental factors on risk of injury of child pedestrians by motor vehicles: A case-control study. *British Medical Journal, 310*(6972), 91–94. http://www.bmj.com/

Rodriguez-Seda, J. D. (2008, January). *Pedestrian, bicycle and vehicle traffic conflict management in Big Ten university campuses.* Paper presented at the 87th TRB Annual Meeting, University of Illinois at Urbana-Champaign, Department of Civil and Environmental Engineering, Washington, DC.

Rogers, G. B. (1997). Factors associated with the crash risk of adult bicyclists. *Journal of Safety Research, 28*(4), 233–241. doi:10.1016/S0022-4375(97)0009-1

Schneider, R. J., Ryznar, R. M., & Khattak, A. J. (2004). An accident waiting to happen: A spatial approach to proactive pedestrian planning. *Accident Analysis & Prevention*, *36*(2), 193–211. doi:10.1016/S0001-4575(02)00149-5

Shafizadeh, K. (2013). *Sacramento State campus intercept survey: 2007–present.* Retrieved from http://www.csus.edu/indiv/s/shafizadehk/CSUS_Intercept_Survey_mode_share.html
Snyder, T. D., & Dillow, S. A. (2013). *Digest of education statistics, 2012* (NCES 2014-015). Washington, DC: National Center for Education Statistics.
Sugerman, K. A. (2011). *UC Berkeley 2011 campus sustainability report.* Berkeley: Office of Sustainability, University of California, Berkeley.
SWOV Institute for Road Safety Research. (2012, February). *SWOV fact sheet: Subjective safety in traffic.* Retrieved from http://www.swov.nl/rapport/Factsheets/UK/FS_Subjective_safety.pdf
UCLA Transportation. (2011). *2011 state of the commute report.* Retrieved from http://www.transportation.ucla.edu/portal/pdf/2011StateoftheCommuteReport.pdf
U.S. Census. (2010). *Interactive population map.* Retrieved from http://www.census.gov/2010census/popmap/
U.S. Department of Transportation. (2010). *The national bicycling and walking study: 15-year status report.* Washington, DC: Author.
Walgren, S. (1998). *Using geographic information system (GIS) to analyze pedestrian accidents.* City of Seattle Transportation Department. Retrieved from http://www.cityofseattle.net/td/ite.asp
Warren, A., Davidson, A., Cervenka, A., Davey, L., & Parsons, K. (2004, July). *Higher education: Bicycle safety for colleges and universities.* New Orleans, LA: Tulane University Office of Environmental Affairs. Retrieved from www.green.tulan.edu/PDFs/Bicycle-Toolkit.pdf
Whalen, K. E., Páez, A., & Carrasco, J. A. (2013). Mode choice of university students commuting to school and the role of active travel. *Journal of Transport Geography, 31*(July), 132–142. doi:10.1016/j.jtrangoeo.2013.06.008
Zegeer, C., Seiderman, C., Lagerway, P., Cynecki, M., Ronkin, M., & Schneider, R. (2002). *Pedestrian facilities users guide—Providing safety and mobility.* University of North Carolina Highway Safety Research Center. McLean, VA: Federal Highway Administration.
Zegeer, C., Stewart, J., Huang, H., and Lagerway, P. (2002). *Safety effects of marked vs. unmarked crosswalks at uncontrolled locations—Executive summary and recommended guidelines* (Report no. FHWA-RD-01-075). Washington, DC: Federal Highway Administration.

Technical Appendix: Survey Instrument

General Questions

1. What is your campus affiliation?
   a. Current student
   b. Current faculty member
   c. Current staff member
   d. No university affiliation
2. What year did you first start traveling to campus?
   a. 2013
   b. 2012
   c. 2011
   d. 2010
   e. 2009
   f. 2008
   g. 2007
   h. 2006
   i. 2005
   j. 2004
   k. 2003
   l. 2002
   m. Before 2002
3. The boundaries of our study for this campus are shown on the map below. Please refer only to locations within these boundaries when completing this survey.
   [map of UCB or UCLA or CSUS]

Accident History

4. Have you biked on or near the campus since 2002?
   a. Yes
   b. No
5. *While biking on or near the campus*, have you had an accident where you fell, you caused someone to fall, or you made contact with another cyclist, a pedestrian, or a vehicle?
   a. Yes
   b. No
6. If yes, please indicate the number of times you have had a biking-related accident.
7. Have you *walked* on or near the campus since 2002?
   a. Yes
   b. No
8. *While walking on or near the campus*, have you had an accident where you fell, you caused someone to fall, or you made contact with another cyclist, a pedestrian, or a vehicle?
   a. Yes
   b. No
9. If yes, please indicate the number of times you have had a walking-related accident.
10. Have you *driven* on or near the campus since 2002?
    a. Yes
    b. No
11. *While driving on or near the campus*, have you had an accident where you fell, you caused someone to fall, or you made contact with another cyclist, a pedestrian, or a vehicle?
    a. Yes
    b. No
12. If yes, please indicate the number of times you have had a driving-related accident.

Accident Details

You reported that you had [number from previous question gets automatically inserted] accidents while biking. Please answer the following questions *for each of these biking accidents.*

13. Please identify the approximate location of the accident in the map below by clicking and dragging the icon. You may also zoom in, move around, and use

the satellite view of the map to help indicate the location more precisely.
[interactive map of the appropriate campus]

14. What year did the accident occur?
    a. 2013
    b. 2012
    c. 2011
    d. 2010
    e. 2009
    f. 2008
    g. 2007
    h. 2006
    i. 2005
    j. 2004
    k. 2003
    l. 2002
    m. Before 2002
    n. Don't know/don't remember
15. What month did this accident occur?
    a. January
    b. February
    c. March
    d. April
    e. May
    f. June
    g. July August September
    h. October
    i. November
    j. December
    k. Don't know/don't remember
16. About what time of the day?
    a. Early morning (3:00 A.M. to 6:59 A.M.)
    b. Morning (7:00 A.M. to 11:59 A.M.)
    c. Afternoon (12 P.M. to 5:59 P.M.)
    d. Evening (6:00 P.M. to 10:59 P.M.)
    e. Late evening (11:00 P.M.to 2:59 A.M.)
    f. Don't know/don't remember
17. Which of the following best describes where the accident took place (please choose only one of the following)?
    a. Sidewalk
    b. Driveway
    c. Roadway/traffic lane
    d. Midblock street crossing
    e. Intersection crossing (with traffic signals)
    f. Intersection crossing (stop signs)
    g. Intersection crossing (without traffic signals or stop signs)
    h. Bike lane on road
    i. Separated bike lane
    j. Multiuse path (bike and pedestrian path)
    k. Parking lot (surface lot)
    l. Parking structure (garage)
    m. Other (please list)
18. Did you make contact with any of the following (check all that apply)?
    a. Contact with a non-moving permanent object (e.g. structure, ground). Please describe.
    b. Another cyclist
    c. A pedestrian
    d. A vehicle
19. What factors do you believe contributed to this accident for each party involved? (check all that apply)
    Myself Other cyclist Pedestrian Vehicle
    a. Inattention
    b. Intoxication
    c. Fatigue or sleepiness
    d. Excessive speed
    e. Riding on the sidewalk
    f. Traveling wrong way
    g. Illegal crossing
    h. Ignoring traffic controls (signals, stop signs)
    i. Failure to yield the right-of-way
    j. Passing or improper lane usage
    k. Unsafe lane change
    l. Avoiding a cyclist, vehicle or pedestrian
    m. Avoiding obstruction (e.g. pothole, tree branch)
    n. Emerging from behind a parked vehicle or other structure
    o. Obstructed views (please explain below)
20. Which of these additional factors do you believe contributed to the accident? (please choose all that apply)
    a. Poor weather conditions
    b. Cracked/uneven sidewalk pavement
    c. Cracked/uneven roadway pavement
    d. Narrow/interrupted bike lane
    e. Obstructed bike lane (e.g. double parking, garbage cans)
    f. Lack of sidewalk
    g. Narrow sidewalk
    h. Driveways interrupting sidewalk
    i. Poor lighting
    j. Don't know/don't remember
    k. Other (please list)
21. How serious was this accident for you? Please choose only one of the following.
    a. Very serious (overnight hospital stay)
    b. Serious (hospital visit, not overnight)
    c. Not serious (scrapes and brusies)
    d. Minor (no visible scrapes or bruises)
    e. No injury (property damage only)
    f. No injury, no property damage

22. How serious was the accident for the other person(s)? Please choose only one of the following.
    a. Very serious (overnight hospital stay)
    b. Serious (hospital visit, not overnight)
    c. Not serious (scrapes and bruises)
    d. Minor (no visible scrapes or bruises)
    e. No injury (property damage only)
    f. No injury, no property damage
23. Did you report the accident to the police?
    a. Yes
    b. No
24. If no, why did you not report the accident to the police? (please choose all that apply)
    a. Thought the accident was minor/not necessary to report
    b. Don't know who to call to report
    c. Didn't think the police would do anything
    d. No time
    e. No one else involved
    f. Other (please explain)
25. You reported that you had [number from previous question gets automatically inserted] accident while walking. Please answer the following questions *for each of these walking accidents.*
    [questions 26 to 37 repeat questions 13 to 24]
38. You reported that you had [number from previous question gets automatically inserted] accidents while walking. Please answer the following questions *for each of these walking accidents.*
    [questions 38 to 49 repeat questions 13 to 24]

Hazardous Sites/Hotspot Locations

50. Are there locations on or near this campus that you think are hazardous for cycling and/or walking?
    a. Yes
    b. No
51. Please identify the hazardous site on the map below by clicking and dragging the icon. You may also zoom in, move around, and use the satellite view of the map to help indicate the location more precisely.
    [interactive map of the appropriate campus]
52. Please indicate if this is a dangerous location for cycling or walking or both.
    a. Cycling
    b. Walking
    c. Both
53. Why do you think this location is dangerous for cycling and/or walking?
    a. Obstructed views
    b. Trees/foliage obstructing visibility
    c. Cracked/uneven sidewalk pavement
    d. Cracked uneven roadway pavement
    e. Inadequate traffic controls (e.g. signals, stop signs)
    f. Inadequate lanes or paths
    g. Lack of sidewalk
    h. Narrow sidewalk
    i. Driveways interrupting sidewalk
    j. Inadequate lighting
    k. Too many vehicles
    l. Too many cyclists
    m. Too many pedestrians
    n. Vehicles travel too fast
    o. Cyclists travel too fast
    p. Other (please list)
    q. Don't know/don't remember
54. Please provide any additional details about this location and why you think it is dangerous for cyclists or pedestrians.
55. Have you experienced a near miss at this location?
    a. Yes
    b. No
56. Please describe the incident.
57. Have you witnessed an accident or near miss at this location?
    a. Yes
    b. No
58. Please describe the incident.
59. Would you like to add another hazardous location?
    a. Yes
    b. No

Respondent Information

60. Gender
61. Year of birth
62. Primary mode to campus (please choose all that apply)
    a. Walking
    b. Cycling
    c. Transit
    d. Drive (alone)
    e. Drive (carpooling)
    f. Other (please describe)
63. How often do you use your primary modes to travel to campus? If you use more than one mode, check any that apply.
    Walk Cycle Transit Drive (alone) Drive (carpool) Other
    5 or more times per week
    3 to 4 times per week
    1 to 2 times per week
    Less than 4 times per month
    Less than once per month
64. Five-digit zip code of your place of residence.