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Latent analysis of Complete Streets and traffic safety along an urban corridor☆

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Abstract

BACKGROUND—To evaluate Complete Street implementations that covary, the present paper aims to: 1) explore the development of typologies of intersections; and 2) examine how these typologies relate to traffic safety.

METHODS—The study site is a five-mile segment in Los Angeles County, California. Multiple indicators of environmental features were collected in 2012 and were included in a latent analysis. Latent classes were then analyzed as a predictor of the number of pedestrian injuries/fatalities and injuries/fatalities for all modes in separate models using negative binomial regression and controlling for exposures. Injuries/fatalities represent the most recent 3 years of crash data available surrounding the environmental data collection (2009–2014). We also examined the role of alcohol.

RESULTS—For a relatively short segment of an urban corridor, we identified two distinct classes of intersections. One class was more complete with respect to pedestrian features but was also associated with indicators of increased potential conflict and was predictive of higher overall injuries/fatalities for all modes. This class also had higher pedestrian volumes but was not predictive of higher pedestrian injuries/fatalities in the final models. The alcohol involvement in crash injuries at these locations did not differ by intersection class but was positively associated

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with injuries/fatalities for all modes and with severe/fatal injuries for pedestrians in the final models.

CONCLUSIONS—Identifying typologies can be used to understand the combination of features and prioritize locations for treatment. While Complete Streets may help counter pedestrian injury trends, the efforts captured in this data are insufficient for municipalities aiming for Vision Zero. Ideally, future research can examine these intersections after the implementation of additional improvements in order to isolate treatment effects. These findings suggest additional intersection countermeasures are needed, in addition to efforts to address social problems such as alcohol use and traffic safety.

Keywords

Complete Streets; pedestrian safety; traffic safety; typologies; vehicle conflict; Vision Zero

1. INTRODUCTION

Active transportation can be important for meeting physical activity recommendations (De Nazelle et al. 2011) and active commuting has been associated with lower body mass index (BMI) among adults (Lindström 2008). Conversely, time spent in cars has been associated with negative health outcomes, including higher BMI (Hoehner et al. 2012; Lopez-Zetina, Lee, and Friis 2006) and increased cardiovascular disease-related mortality (Warren et al. 2010). Additionally, there are environmental (De Nazelle et al. 2011) and other (Mattisson, Hakansson, and Jakobsson 2014) benefits to active travel. As such, several national, state, and often local efforts aim to increase active transportation and walking (Office of the Surgeon General 2015).

Multiple studies indicate that the built environment impacts whether and how much people walk. People who live in walkable neighborhoods walk more than those who do not, controlling for self-selection, and people living in these types of neighborhoods are generally less likely to be overweight or obese (Saelens et al. 2003; Frank et al. 2007). Recent longitudinal studies provide support for building walkable environments to increase physical activity (Hirsch et al. 2014; Knuiman et al. 2014). Well-established environmental dimensions of walkability include population density, land use diversity, connectivity, and destinations that will attract pedestrians (Ewing and Cervero 2010; Frank et al. 2010; Saelens and Handy 2008).

While numerous benefits of active travel have been documented, research has also found significant barriers to active travel, including fear of traffic danger (Dill, Toulan, and Voros 2006; Schlossberg et al. 2008). This fear is not unfounded: pedestrians and bicyclists lack the protection of motor vehicles (thus the name “vulnerable road users”), and the data bear this out: accounting for exposure, compared to other roadway users, pedestrians are the leading fatally injured mode per person trip (Beck, Dellinger, and O’Neil 2007). Most U.S. communities are designed to favor motor vehicles. Reducing conflict with motor vehicles, improving visibility of pedestrians, reducing motor vehicle speeds, and increasing awareness are effective countermeasures (Campbell et al., n.d.). Unfortunately, by designing roadways to facilitate throughput using speeds incompatible with vulnerable road users, many communities have inadvertently prioritized motorists over that of pedestrians and bicyclists. The Complete Streets movement has sought to remedy this trend by encouraging street design that clearly welcomes and accommodates pedestrians, bicyclists, drivers, and transit and truck traffic where applicable. However, as municipalities increasingly adopt the goal of Vision Zero, the impact of improvements associated with the Complete Streets principles are still being evaluated. As people are encouraged to walk and bicycle more to increase physical activity, are they safer doing so?

In an effort to understand mobility and safety in an urban corridor, the California Department of Transportation (Caltrans) initiated this project to examine how environmental features affect pedestrian, bicyclist, and driver safety and mobility. These features can be correlated within an intersection and along a corridor. The present paper focuses on identifying these patterns and how they relate to pedestrian safety, bicycle safety, and overall traffic safety.

2. MATERIAL AND METHODS

2.1. Study Site

The study site is in Los Angeles County, California, U.S.A. This study was conducted on the five-mile segment (or approximately 8 km) of Santa Monica Boulevard running from the western border of West Hollywood to its intersection with Highway 101 in the City of Los Angeles. Santa Monica Boulevard is a State Route that acts as an urban arterial in Los Angeles. The West Hollywood section is also an urban arterial, but this section was relinquished from the California Department of Transportation to the City of West Hollywood in 1999. A reconstruction project in 2001 included the design of many landscape, pedestrian, and bicyclist features for the West Hollywood section.

Urban arterials or corridors in the U.S. are a type of highway that typically have a high concentration of commercial and retail attractions, often in addition to multi-family residential buildings, urban arterials act as a magnet for all types of traffic.

2.2. Data

In addition to police reported traffic crash data, data for this study include an inventory of landscape and design features along with other characteristics of the corridor including speed and vehicle and pedestrian volume.

2.2.1. Environment—The research team developed a checklist to facilitate data gathering. The checklist included elements needed to perform the National Cooperative Highway Research Program’s Multimodal Level of Service Analysis for Urban Streets, which assesses how well various roadway users’ needs are met on an urban street. The San Francisco Pedestrian Environmental Quality Index was also used for the facility analysis. Data were recorded on intersection features (e.g. marked crosswalks), segment features (e.g. sidewalk conditions), land use (e.g. business), landscaping (e.g. shade trees), sources of conflict (e.g. crossing distances), and traffic calming measures (e.g. median widths). (See Appendix A for facility checklist).

Data for Santa Monica Boulevard was first collected using Google Maps™ Street View and Google Earth™ to record design features and measurements on paper forms as well as to verify that features were present along the corridor for the entire ten-year study period. Data were collected between October 2011 and March 2012. Not all measurements could be recorded using Google Earth™ because of lack of visibility. The measurements and observations were then field verified and completed during a site visit with good weather between Tuesday, March 27, 2012 and Thursday, March 29, 2012. Standard engineering measuring wheels and stop watches were used to measure distance and time. Data was gathered for each of the 80 intersections and the roadway segments between intersections. After the data was gathered manually, it was input into a Microsoft Excel™ spreadsheet.

2.2.2. Crashes—The number of overall injuries (all modes including vehicle passengers) and pedestrian (includes those in or operating a pedestrian conveyance such as baby carriage, skateboard, wheelchair) injuries served as the measures of safety and was determined using the California Statewide Integrated Traffic Record System (SWITRS). SWITRS is an electronic database of police-reported traffic collisions maintained by the California Highway Patrol (CHP). CHP and all local law enforcement agencies in the state are required by law to submit data on all police-reported collisions. Crashes have been found to be underreported by injury severity, as determined from comparing crash data to other data sources; therefore, we also include fatal and severe injuries as a separate outcome, as these injuries are of particular interest and also tend to be more complete in terms of reporting (Arnold et al. 2010). The most recent geocoded SWITRS data available is for the year 2014. Therefore, we include the most recent 3 years surrounding the data collection period (2012). SWITRS data for 2009–2014 that occurred within 200 feet of the study intersection were included. Intersections are common places where pedestrians and vehicles conflict and are often riskier in urban areas (Chen and Zhou 2016). Some studies have been more conservative with the distance criteria for pedestrian crashes; however, research using SWITRS data indicates that a majority of pedestrian, bicycle, and motor vehicle crashes are captured within 200 feet (Zhang, Pande, and Grembek 2012).

2.2.3. Volumes—Motor vehicle volumes were obtained from the tube counts conducted in 2012. The mean and median volumes were 31,949 and 31,985 respectively (range 25,260–36,069). Because consistent data for the vehicle volume of side streets along the corridors was not available, a proxy variable was use to indicate whether the side streets carried high or low vehicle volumes in comparison with the remainder of the corridor.

Pedestrian volume counts were not available, so a pedestrian volume model was built for this project. Based on prior research, (Schneider, Arnold, and Ragland 2009) the research team used a combination of short-term and continuous pedestrian counts, as well as adjustment factors, to estimate volumes. For this project, 4-hour pedestrian counts (between 2 and 6 p.m. on a Tuesday, Wednesday, or Thursday) were collected by a professional traffic counting firm at eleven different locations throughout the Santa Monica Boulevard corridor. The counts were conducted during the summer months of June and July 2012, on average days (weather or otherwise) for the locations. Pedestrians were counted for each leg of the intersection they crossed to provide an accurate representation of exposure to potential crashes. In addition, project Eco-Counters collected continuous (i.e., 24-hour) counts for multiple weeks at three other locations throughout the corridor. These counts provided insight into pedestrian volume trends by time of day and day of week at various locations throughout the corridor. One continuous site was located next to a school to illustrate how pedestrian patterns vary by whether school is in session.

The 4-hour counts were then extrapolated to weekly volumes based on hourly adjustment factors created from the continuous counter data. Estimates for intersections near schools were calculated separately based on data corresponding to counts near a school and corresponding to time periods when school was in session. No adjustments were made to account for weather because of the mild and relatively consistent weather patterns in Los Angeles County.

Using the weekly volume projections at the eleven locations, a pedestrian model was built to associate different land use and design feature elements with pedestrian volume in an effort to predict volume exposure. The literature review suggested a log linear methodology, as well as several variables expected to be associated with pedestrian volume, including demographic variables obtained from the Census, design and landscape features, and land use characteristics. The final pedestrian volume model included variables indicating the total number of retail on both blocks surrounding an intersection, the presence of public art on both blocks, the presence of tree grates on both blocks, and the signalization of the intersection. The research team believed these associations to be reasonable because retail and high quality locations are likely to attract pedestrians. Additionally, pedestrian intersection crossing volumes are likely to be higher at locations with a signal providing pedestrians with a form of protection.

Using the model configuration presented above, weekly pedestrian volumes were calculated for each intersection within the corridor. The weekly volumes were then multiplied by 52 weeks per year and then again by 6 years to project exposure for the six-year period during which crashes are evaluated. Variables selected for the final model were excluded from the crash models. The correlation between the weekly volumes and the modeled volumes at the 11 locations was 0.94.

2.3. Data Analysis

The goals of the analyses are to: 1) explore the development of classes or categories of intersections; and 2) examine how these classes are related to traffic safety, controlling for exposure.

2.3.1. Unit of analysis—The unit of analysis was the intersection (n=80). Features along a segment leading to the intersection that could influence drivers (e.g. traffic calming) were summarized west and east of the intersection.

2.3.2. Latent analysis—Latent analysis, a mixture model that uses observed indicators to identify latent variables predicting the probability of attributes or patterns within classes or groups, was conducted. This approach can assist with issues of multi-collinearity and allows for important covariation. The use of continuous, observed indicators is considered latent profile analysis. The use of categorical, observed indicators is considered latent class analysis. Mplus software allows for the inclusion of both categorical and continuous indicators for these types of analyses (Muthén, Linda. Mplus Discussion, 2010). While we utilize more continuous, observed indicators, we will refer to the analyses as latent class analysis (LCA) as readers may be more familiar with LCA. We applied hierarchical exclusions to the available set of variables as follows: 1) variables that were included in the pedestrian volume models; 2) variables that did not vary; 3) variables that were captured by another variable; and 4) variables that did not make conceptual sense to include given the present objective.

Multiple indicators of landscape and design features and vehicle speeds were included. LCA models were evaluated based on indicators of separation between classes and internal cohesion within classes. A Lo-Mendell-Rubin test was used to compare the current n-class model to an (n-1)-class model. All analyses were conducted using Mplus 7 (Muthén & Muthén, Los Angeles, CA).

2.3.3. Negative binomial analyses of injuries and fatalities—Negative binomial is an appropriate approach for count outcomes and relaxes the variance assumption required for Poisson regression. Bivariate and multivariable negative binomial analyses were conducted with the number of injuries for all modes (range 1–103) and pedestrians (0–35) for a 6-year period (2009–2014) as the dependent variables. The main predictors were the latent categories (i.e. intersection types) analyzed as a categorical predictor. In addition, we examined the percentage of injuries that involved alcohol (not necessarily by the injured victim) as a predictor. In California, pedestrian injury rates tend to be positively associated with proximity to alcohol outlets (Schneider et al. 2010). In the U.S., alcohol use plays a substantial role in pedestrian fatal hit-and-runs (MacLeod et al. 2012). Multivariable analyses controlled for pedestrian exposure (log transformed pedestrian volumes). All analyses were conducted using SAS 9.3 (SAS Institute, Cary, NC).

3. RESULTS

3.1. Latent analysis results

A Lo-Mendell-Rubin test indicated a 2-class model was a better fit than a 3-class model (p=0.47). Table 1 shows environmental characteristics summarized by the 2 classes, and Figure 1 shows the class types mapped. Variables that classed particularly well represented sources of potential conflict with vehicles (crossing distances, the presence of left turn lanes, number of lanes on primary street, secondary street classification) and pedestrian facilities (accessible curb ramps, pedestrian features, crosswalks). Class 2 appears to be a more “complete” intersection, with more crosswalks, accessible curb ramps, and bus stops associated with these intersections (Table 1); potentially more important, these intersections were also more likely to be the intersection of two major roads. Relatedly, the average crossing distances were roughly 10 and 20 feet longer for primary and secondary streets, respectively, in class 2 compared to class 1 (Table 1). Average pedestrian volumes were also higher in class 2 compared to class 1. The involvement of alcohol at locations did not differ significantly by class type.

3.2. Negative binomial results

Table 2 shows injuries for all modes of travel by all injury severity levels and by severe/fatal injuries. Motor vehicle volumes were negatively related to all injury levels but not significantly related to severe/fatal injuries. While this may appear counterintuitive at first glance, it may reflect the reality that high traffic volumes are often associated with congestion and slower vehicle speeds, which, can be better for traffic safety (Evans, 2004). Indeed, more “complete” intersections (class 2), which were significantly more likely to occur at the intersection of two major roads, were associated with more injuries (p<0.05) and severe/fatal injuries (p<0.10; Model 2) controlling for mainline vehicle volume and pedestrian exposure and accounting for alcohol involvement. The role of alcohol was also a significant positive predictor and remained significant after considering the intersection typologies. Table 3 shows pedestrian injuries by all injury severity levels and by severe/fatal injuries. The leading predictor for all pedestrian injuries was motor vehicle volume, while alcohol involvement was the leading predictor for severe/fatal pedestrian injuries in the final models.

4. DISCUSSION

For a relatively short segment (5 mi or 8 km) of an urban corridor in Los Angeles, we identified two distinct classes of intersections based on environmental features. One class was more “complete” and had more pedestrian features and was associated with higher pedestrian volumes. In this cross-sectional study, this class also had greater sources of potential conflict and was predictive of injuries/fatalities for all modes, even after controlling for vehicle and pedestrian volumes. This class was also positively and marginally related to pedestrian injuries/fatalities, but did not reach statistical significance in the final models. For severe/fatal injuries for pedestrians and for all modes, alcohol involvement was a leading predictor.

Given the higher pedestrian volumes and general potential for conflict at the more complete intersections (a greater number of bus stops, crossing distances, etc.), it is possible that the pedestrian features at these intersections helped counter a trend towards higher severe and fatal pedestrian injuries, that would have otherwise been more evident. In some ways, this paper illustrates how the Complete Streets and Vision Zero movements can work together to advance traffic safety for all modes. Complete Streets focuses on safely accommodating all users on the roadway. While noble, the findings in this paper demonstrate that intersections can be “improved” for some modes but may still be dangerous if influential underlying factors, such as conflict between roadway users, remain unchanged. Vision Zero efforts can complement the Complete Streets movement by helping hone the focus to preventing severe injuries and fatalities through strategies such as separating users in time and space, whether that be reducing vulnerable road users’ exposure to vehicles, or reducing the exposure of vehicles to each other, e.g., through better controlling turns. Other societal factors are also important. The history of alcohol involvement for crash injuries at the study locations did not differ by location type but was positively associated with severe and fatal injuries. In the U.S., alcohol use continues to be a concern for traffic safety. Drinking and driving plays a role in pedestrian fatal hit-and-runs (MacLeod et al. 2012), and pedestrian injury rates are correlated with the proximity to alcohol outlets (Schneider et al. 2010). Alcohol use among pedestrians is also a leading factor in pedestrian crashes (Karsch et al. 2012), as it is for motorists in motor vehicle crashes (NHTSA, 2016). Vision Zero's work to alter traffic safety culture is another crucial way that it can complement the Complete Streets movement.

4.1. Intersection typologies

Researchers are starting to use latent class analysis and latent profile analysis to address the complexities of studying place (Jones and Huh 2014; Weden et al. 2011; Todd et al. 2016) as many features that are of interest or are of nuisance can covary. In our latent analysis, we identified two distinct types with some key differences between these types or classes. First, traditional indicators of conflict continue to be a challenge for road users. Average crossing distances were longer for more "complete" locations (class 2). This means that all users—pedestrians, bicyclists, and motorists are exposed to potential conflict with vehicles for longer while crossing at those intersections. In addition, and relatedly, class 2 intersections were more likely to be intersections of two major streets. AADT for side streets was not available for all locations and therefore was not tested in the model, but the longer crossing distances on the side streets and the side street classification were likely acting in part as proxies for higher total intersection vehicle volume.

Second, aspects of the built environment and intersection design may affect road user safety. The number of bus stops tended to be higher with class 2 intersections. This may be acting as a proxy for activity: bus stops tend to be located at places that may have more pedestrian and auto volumes, and are natural points for people to want or need to cross a street. Depending on how they are designed, they may also make it harder for drivers to see pedestrians trying to cross, particularly in multi-lane situations where the large bus blocks visibility of the curb. Class 2 was also associated with the presence of left turn lanes, which again generally correspond to busier intersections with more complex interactions. The fact that class 2 intersections were also significantly more likely to have more crosswalks, accessible curb ramps, and other pedestrian features may therefore seem surprising, but it is likely that these features were installed to mitigate some of the danger to pedestrians from the otherwise busy, complex intersection. If these features were not present, it is likely that these locations would have been even more dangerous for pedestrians and potentially other road users.

For roadway safety in the U.S., strategies to reduce pedestrian exposure to vehicles include sidewalks, curb ramps, traffic signals, medians, restricting turning movements, and other pedestrian features to increase awareness of pedestrians (*A Guide for Reducing Collisions Involving Pedestrians* 2004). In addition, exclusive pedestrian signal phasing, pedestrian refuge islands, and high intensity roadway lighting are also highly effective (Retting, Ferguson, and McCartt 2003). Several of these strategies are present at class 2 intersections. This suggests that the combination of features at the Class 2 intersections was not enough to prevent pedestrian fatalities. Multiple indicators of increased potential conflict suggest that additional countermeasures to restrict turning movements of vehicles may help. Countermeasures that completely separate vehicle and pedestrian movements, such as the "pedestrian scramble" (aka "Barnes Dance") and protected left turns, improve predictability for all users and have been found to be effective for reducing injury (Bechtel, MacLeod, and Ragland 2004). Because Santa Monica Boulevard carries so much traffic, people may be concerned about delays if motorists' movements are restricted. However, additional safety improvements at these intersections could improve safety for all modes, fitting with Los Angeles's commitment to Vision Zero.

4.2. Implications for Practice and Policy

Cities across the U.S.—including Los Angeles (the study site for the present paper)—have adopted or are considering adopting the goal to eliminate traffic fatalities, known as "Vision Zero." Key to the success of this movement is the understanding that most traffic crashes are not random; rather, the built environment and behavior work together to cause fatal and injurious crashes, as shown in this paper and many prior studies (Fernandes, Miranda-Moreno, and Morency 2012; Gårder 2004; Lee and Abdel-Aty 2005; Ukkusuri, Hasan, and Aziz 2011).

A first step in understanding crash patterns is to employ strategies such as hot spot analysis and crash typing, which identify priority locations and traffic safety countermeasures. Systemic analysis takes this a step further to identify features of the environment that attract roadway users and can act to hinder or support pedestrian, bicyclist, and motorist safety (Preston et al. 2013). Latent class and latent profile analysis, which allows for covariation of indicators, can be another tool for identifying patterns regarding environmental characteristics. These strategies—particularly those with a systemic focus—are a key part of any Vision Zero effort, as they can assist municipalities in identifying locations and patterns that can aid in proactively addressing safety, rather than waiting for crashes to occur before making changes.

Additionally, becoming clear about the priority of various goals seems paramount in the pursuit of Vision Zero. The Complete Streets movement has successfully fought for space for bicyclists and pedestrians so that people have options for travel. Critically, however, many municipalities have made concessions for pedestrians and bicyclists—such as improved intersection crossings and bike lanes—without addressing key aspects of corridors that make travel dangerous for all roadway users. For example, a high-visibility crossing draws attention to a pedestrian, but a driver going too fast may not have time to react and slow down; similarly, multi-lane streets are the sites of "multiple-threat" crashes that occur when one driver slows for a crossing pedestrian and the driver in the next lane does not, tragically ending in a pedestrian injury or fatality. The goal of zero helps to focus municipalities' efforts on making the wholesale changes to the context so that drivers are not asked to react as quickly because they are not traveling so fast, thus giving everyone a better chance to travel safely along that corridor. Interestingly, many Vision Zero efforts are finding that driver fatalities are also prevalent along the major arterials that are problematic for pedestrians (Portland Bureau of Transportation, 2017). Improvements made in pursuit of Vision Zero help save *all* lives.

Furthermore, identifying combinations of features that are more likely to be associated with injuries or fatalities can help municipalities develop targeted performance measures to monitor improvements over time. For example, most performance measures focus on outcomes, such as numbers of pedestrian injuries and fatalities over time. While it is critical to measure these numbers, it may be just as important to measure the presence of outputs known to lead to the outcomes, such as the number of corridors with speed limits over 30 mph in a city, or the percentage of intersections along major arterials with a combination of features known to be associated with greater pedestrian injury. Developing these measures will likely be an important part of creating accountability within Vision Zero efforts.

Finally, analysis of built environment and roadway data will be important to supplement any crash analysis so that engineers, planners, and policymakers can understand how various characteristics contribute to or detract from traffic safety for all modes. While conducting an environmental audit can be resource intensive, it is important for a comprehensive analysis. We used Google Streetview™ to assist in our data collection efforts; such tools may help ease the burden of on-site data collection (Kurka et al. 2016).

4.3. Limitations and Future Research

We utilized an analytic method to differentiate types of intersections along a relatively short segment of an urban corridor. While we were able to distinguish many features, we could not distinguish all features included in the latent analysis. In some cases, this could be due to statistical power. However, it is likely that in other cases those features did not differ enough to show. In addition, some of our findings may not be generalizable to all urban corridors. Future studies could analyze intersections from different corridors to strengthen or clarify these findings. We also did not examine potential influences that may exist outside of the built environment, including the culture and socio-demographics of the areas surrounding the intersections and of the people involved in the crashes. We include the involvement of alcohol, which, can be tied to both the social and physical environment. However, other social and cultural factors might influence traffic safety values and behaviors. Future research could try to discern the relative contributions of the built environment compared to these other factors. Additionally, while we utilized several years of crash data because fatalities can be relatively infrequent, we conducted our environmental assessment at one point in time and without the information to control when the improvements were made; it is possible that the improvements in the Class 2 intersections were more impactful than the analyses suggest. Future research could include case studies of intersections and before and after studies of intersection changes to address some of the limitations of cross-sectional studies. For example, a before and after study of an urban freeway with landscape improvements observed some improvements in pedestrian fatalities (Mok, Landphair, and Naderi 2003). Along a short segment of a single corridor it may be difficult to isolate features without natural or randomized experiments. Finally, it is possible that some locations are safer as determined by crash data because pedestrians perceive them to be unsafe and avoid these areas. Case studies and focus groups would assist in better understanding such issues.

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APPENDIX A. FACILITY CHECK LIST

Facility Checklist

*Intersection: Hwy 82 & Wilson Ave Date: ______
All information on roadway segment should refer to the section ***south/west*** *of the intersection.* Time: ______
Google Earth Imagery Date:

Were significant changes noted in google earth history? If so, note the approximate date and changes that occurred:

Bike Facilities	NB/EB	SB/WB
Bike lane presence (y/n; width)		
On-street parking on main street (y/n)		
Total number of parking spaces available		
Number of occupied on-street parking spaces on main street		
Ave. pavement surface condition rating in bike lane (3 = good: smooth, 2 = fair: passable, 1 = poor: dangerous/not passable)		
Percent of bicycle lane mileage in fair or better condition (at least 2 in pavement rating)		
Ratio of Class II (striped) bicycle facility mileage to centerline roadway mileage, bidirectionally (approximate)		
Percent of primary street designed as a complete street (including bicycle facilities, sidewalks, and motor vehicle travel lanes)		
Bike parking (total # spaces; 1 U rack = 2 spaces)		
Number of parked bikes		
Bike lockers (#)		
Marketing campaign to encourage cycling (y/n)		
Bicycle wayfinding signage (y/n)		
Effects of Transit (conflicts evident - y/n)		
Grade (level, uphill, downhill)		
The intersection has one or more of the following: bike box, bike lane through intersection, bike signal, bicycle detectors, bike left turn lane (y/n and circle ones that are present)		

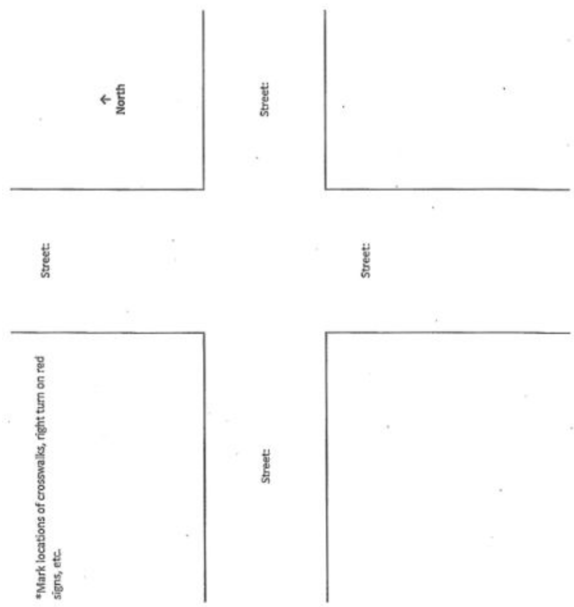
Transit Accessibility	NB/EB	SB/WB
Number of transit stops within 0.25 mile of segment		
% of transit stops with benches		
% of transit stops with shelters		
For each transit line serving the area:		
Frequency		
% on time		
Average load (% of capacity)		
Average bus speed		

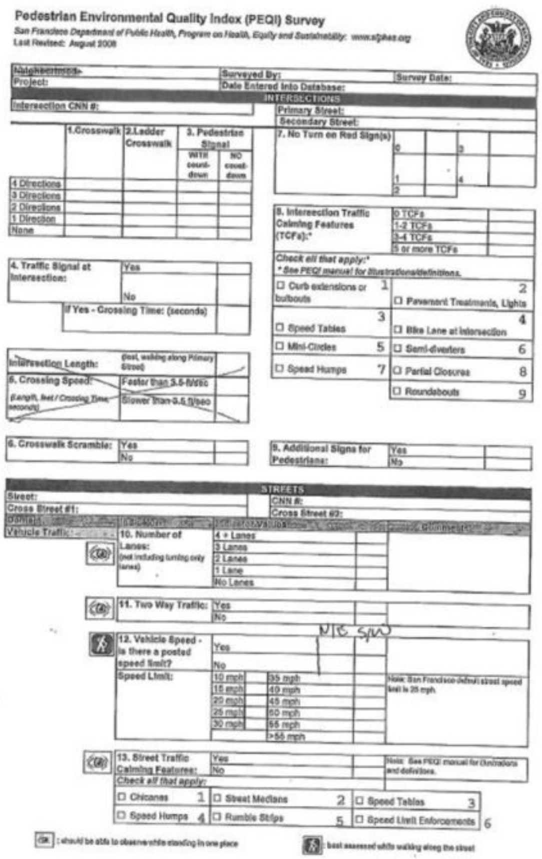
Other		
Two-way left turn lane (y/n, width if y)		
Channelized/yield Right turn? (y/n, note approaches for y)		
Number of residential driveways?		
Number of commercial driveways? (parking garages count as 2)		
Number of large commercial parking lots?		
Distance to next downstream intersection (in ft)		
Land Use (Commercial, Industrial, Residential)		
Intersection Type		

Pedestrian Facilities		
Ratio of sidewalk mileage to centerline roadway mileage, bidirectionally		
Percent of sidewalk mileage in fair or better condition (at least 3 on scale of 5 = excellent, 1 = poor)		
Percentage of sidewalk that is ADA accessible (min. 5' width, slope, cross-slope)		
Percentage of sidewalk constructed with context sensitive materials, colors, or patterns		
Median has landscaping (y/n)		
Median landscaping type (grass, shrub, tree -list number of trees)		
Frequency of median landscapign (regular, sporadic, none)		
Median passable (y/n)		
Average Median Width (feet)		
Mid-block crossing (y/n)		
Mid-block signage or traffic calming (y/n)		
Trash receptacles present (#)		

	NB/EB	SB/WB
Buffer between curb and sidewalk? (note width)		
Lane Widths (use common section if it varies across lanes)		
Number of intersection legs/crosswalks constructed with context sensitive materials, colors, or patterns		
*Is a **signalized intersection** with **marked crosswalks** and one or more of the following: pedestrian countdown signals, leading pedestrian intervals, bulb-outs, or pedestrian refuge islands (y/n, mark ped element)* (yield to ped signage)		
*Is an **unsignalized 4-lane (multilane) intersection** with **marked crosswalks** and one or more of the following: yield to pedestrian signage, user-activated overhead or in-ground warning lights (y/n, mark ped element)* (bulb outs, ped refuge islands)		
Percent of the intersection with curb ramps, truncated domes, or both (mark where)		
Median refuge (y/n, width) ~~(note if raised or just surrounded by raised med.)~~		
Left turn lanes at intersection (y,/n, #, width) (main street)		
Left turn lanes at intersection (y,/n, #, width) (side street)		
Right turn lanes at intersection (y,/n, #, width) (main street)		
Right turn lanes at intersection (y,/n, #, width) (side street)		
Intersection/Crosswalk Length: North Side & width		
Intersection/Crosswalk Length: South Side & width		
Intersection/Crosswalk Length: East Side & width		
Intersection/Crosswalk Length: West Side & width		
Crossing Time: North Side		
Crossing Time: South Side		
Crossing Time: East Side		
Crossing Time: West Side		
Total number of lanes that must be crossed by pedestrian (along main street)		
Total number of lanes that must be crossed by pedestrian (crossing main st)		
If applicable: Intersection/Crosswalk Length: 5th Leg		
If applicable: Crossing Time: 5th Leg		
If applicable: Total number of lanes that must be crossed by ped (5th leg)		

Other Observations or Comments:
Gas stations:
Hotels:
School(s)?





Pedestrian Environmental Quality Index (PEQI) Survey

San Francisco Department of Public Health, Program on Health, Equity and Sustainability: www.sfphes.org
Last Revised: August 2008

Neighborhood:
Project:
Surveyed By:
Survey Date:
Date Entered Into Database:

INTERSECTIONS

Intersection CNN #:
Primary Street:
Secondary Street:

	1.Crosswalk	2.Ladder Crosswalk	3. Pedestrian Signal WITH count-down	3. Pedestrian Signal NO count-down
4 Directions				
3 Directions				
2 Directions				
1 Direction				
None				

7. No Turn on Red Sign(s): 0, 1, 2, 3, 4

4. Traffic Signal at Intersection: Yes / No
If Yes - Crossing Time: (seconds)

8. Intersection Traffic Calming Features (TCFs):* 0 TCFs / 1-2 TCFs / 3-4 TCFs / 5 or more TCFs
Check all that apply:
** See PEQI manual for illustrations/definitions.*
☐ Curb extensions or bulbouts 1
☐ Pavement Treatments, Lights 2
☐ Speed Tables 3
☐ Bike Lane at intersection 4
☐ Mini-Circles 5
☐ Semi-diverters 6
☐ Speed Humps 7
☐ Partial Closures 8
☐ Roundabouts 9

Intersection Length: (feet, walking along Primary Street)
6. Crossing Speed: Faster than 3.5 ft/sec / Slower than 3.5 ft/sec
(Length, feet / Crossing Time, seconds)

6. Crosswalk Scramble: Yes / No

9. Additional Signs for Pedestrians: Yes / No

STREETS

Street:
CNN #:
Cross Street #1:
Cross Street #2:

Vehicle Traffic

10. Number of Lanes: (not including turning only lanes) 4 + Lanes / 3 Lanes / 2 Lanes / 1 Lane / No Lanes

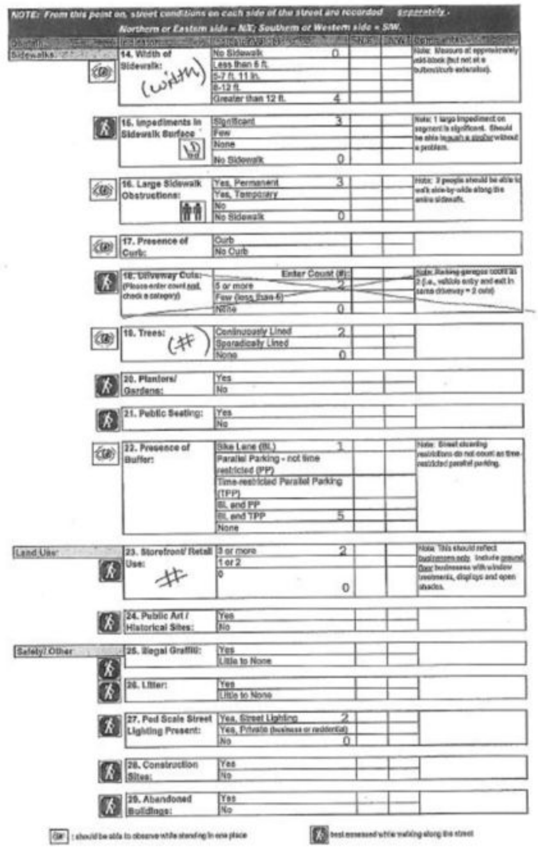
11. Two Way Traffic: Yes / No

N/S S/W

12. Vehicle Speed - Is there a posted speed limit? Yes / No
Speed Limit: 10 mph / 15 mph / 20 mph / 25 mph / 30 mph / 35 mph / 40 mph / 45 mph / 50 mph / 55 mph / >55 mph
Note: San Francisco default street speed limit is 25 mph.

13. Street Traffic Calming Features: Yes / No
Note: See PEQI manual for illustrations and definitions.
Check all that apply:
☐ Chicanes 1
☐ Street Medians 2
☐ Speed Tables 3
☐ Speed Humps 4
☐ Rumble Strips 5
☐ Speed Limit Enforcements 6

: should be able to observe while standing in one place
: best assessed while walking along the street



NOTE: From this point on, street conditions on each side of the street are recorded separately. Northern or Eastern side = N/E; Southern or Western side = S/W.

[illegible]	[illegible]	[illegible]		[illegible]	[illegible]	[illegible]
Sidewalks	14. Width of Sidewalk: (width)	No Sidewalk	0			Note: Measure at approximately mid-block (but not at a bulbout/curb extension).
		Less than 6 ft.				
		5-7 ft. 11 in.				
		8-12 ft.				
		Greater than 12 ft.	4			
	15. Impediments in Sidewalk Surface	Significant	3			Note: 1 large impediment on segment is significant. Should be able to push a stroller without a problem.
		Few				
		None				
		No Sidewalk	0			
	16. Large Sidewalk Obstructions:	Yes, Permanent	3			Note: 2 people should be able to walk side-by-side along the entire sidewalk.
		Yes, Temporary				
		No				
		No Sidewalk	0			
	17. Presence of Curb:	Curb				
		No Curb				
	18. Driveway Cuts: (Please enter count and check a category)	Enter Count (#):				Note: Parking garages count as 2 (i.e., vehicle entry and exit in same driveway = 2 cuts)
		5 or more	2			
		Few (less than 5)				
		None	0			
	19. Trees: (#)	Continuously Lined	2			
		Sporadically Lined				
		None	0			
	20. Planters/ Gardens:	Yes				
		No				
	21. Public Seating:	Yes				
		No				
	22. Presence of Buffer:	Bike Lane (BL)	1			Note: Street cleaning restrictions do not count as time-restricted parallel parking.
		Parallel Parking - not time restricted (PP)				
		Time-restricted Parallel Parking (TPP)				
		BL and PP				
		BL and TPP	5			
		None				
Land Use	23. Storefront/ Retail Use: #	3 or more	2			Note: This should reflect businesses only. Include ground floor businesses with window treatments, displays and open shades.
		1 or 2				
		0	0			
	24. Public Art / Historical Sites:	Yes				
		No				
Safety/ Other	25. Illegal Graffiti:	Yes				
		Little to None				
	26. Litter:	Yes				
		Little to None				
	27. Ped Scale Street Lighting Present:	Yes, Street Lighting	2			
		Yes, Private (business or residential)				
		No	0			
	28. Construction Sites:	Yes				
		No				
	29. Abandoned Buildings:	Yes				
		No				

: should be able to observe while standing in one place — best assessed while walking along the street

Highlights

- We conducted a cross-sectional environmental audit of an urban corridor in LA
- Based on this audit, we identified two distinct classes of intersections
- Complete intersections had greater pedestrian volumes and sources of conflict
- Complete intersections also had more injuries for all modes but not for pedestrians
- Complete Streets may help counter some injury trends but more work is needed

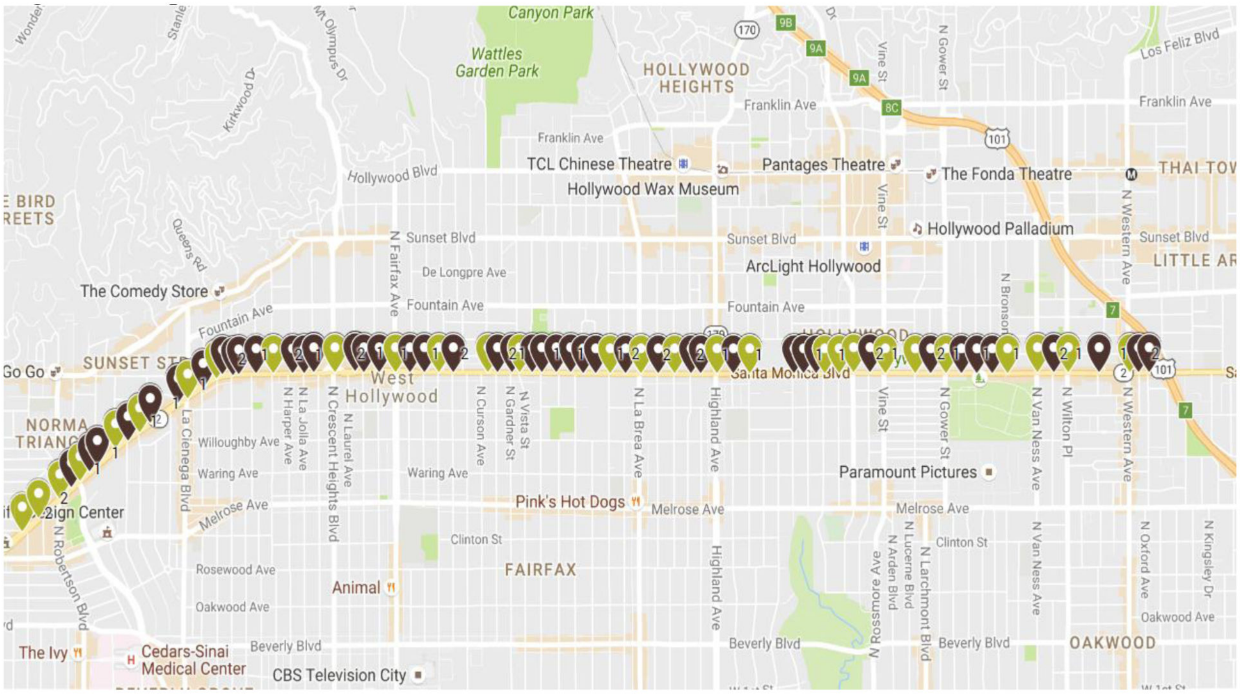


Figure 1.

Map of Classes

Source: Google Maps. Dark dot indicates class 1.

TABLE 1

Summary of characteristics by class

	Class 1 (n=51)		Class 2 (n=29)		
	Mean	**SD**	**Mean**	**SD**	***p***
Not included in latent analysis					
Motor vehicle volume on main street	31,989	2,747	31,878	3,326	0.87
Pedestrian volume for a 10-year period (Source: Modeled from counts and sensors)	7,478,936	5,218,231	13,915,289	7,339,229	<0.001
Percent of injuries that involve alcohol (Source: SWITRS)					
All modes, all injury levels	13.36	10.55	14.21	9.53	0.72
All modes, severe/fatal injuries	14.77	31.52	15.92	28.91	0.87
Pedestrian, all injury levels	19.91	30.32	16.41	21.33	0.55
Pedestrian, severe/fatal injuries	12.75	32.55	17.24	33.77	0.56
Included in latent analysis					
Crossing distance on main street (feet)	61.69	11.18	70.71	18.24	<0.05
Crossing distance on secondary street (feet)	39.38	8.37	60.45	18.55	<0.0001
Number of lanes on main street	4.35	0.59	4.66	0.61	<0.05
Speed (Source: tubes)	32.45	1.30	32.80	1.32	0.25
Percent of curbs that accommodate disabled	56.63	23.57	97.97	7.70	<0.0001
Median width (feet)	2.32	3.10	3.13	4.50	0.39
Percent of crosswalks that are marked	33.33	22.55	95.11	11.03	<0.0001
Landuse: Number of industrial buildings per 1000 feet	0.43	1.37	0.87	2.02	0.24
Number of trees per 1000 feet	43.77	42.07	36.41	29.70	0.36
Bus stops per 1000 feet	1.14	0.92	1.79	0.77	<0.01
Number of commercial driveways per 1000 feet	9.41	7.21	10.01	7.37	0.73
	n	**Column %**	**n**	**Column %**	***p***
Left turn lanes at intersection	22	43.14	28	96.55	<0.0001
Presence of advanced yield lines at intersection	28	54.90	15	51.72	0.78
Secondary street classified as major road	0	0.00	14	48.28	<0.0001
Intersection has pedestrian features	14	27.45	25	86.21	<0.0001

P-values were obtained from the Student’s t-test for continuous variables and the Chi-square or Fisher’s exact test for categorical variables.

TABLE 2

All modes, SWITRS 2009–2014

	Bivariate					Model 1					Model 2				
	Est	SE	95% CI		*p*	Est	SE	95% CI		*p*	Est	SE	95% CI		*p*
All injury levels															
Class															
1	ref					ref					ref				
2	0.4608	0.1552	0.1567	0.7650	***	0.3785	0.1771	0.0315	0.7255	**	0.4309	0.1735	0.0909	0.7708	**
Motor vehicle volume	−0.0001	0.0000	−0.0001	−0.0000	**	−0.0000	0.0000	−0.0001	0.0000	*	−0.0001	0.0000	−0.0001	−0.0000	**
Pedestrian volume (log)	0.2159	0.1175	−0.0145	0.4462	*	0.0672	0.1297	−0.1871	0.3215	0.60	−0.0257	0.1314	−0.2832	0.2318	0.85
Percent that involve alcohol	0.0174	0.0089	−0.0000	0.0348	**						0.0200	0.0084	0.0036	0.0365	**
Severe/Fatal Injuries															
Class															
1	ref					ref					ref				
2	0.4775	0.3046	−0.1195	1.0745	0.12	0.5190	0.3610	−0.1885	1.2266	0.15	0.6293	0.3389	−0.0348	1.2935	*
Motor vehicle volume	0.0000	0.0000	−0.0001	0.0001	0.84	0.0000	0.0000	−0.0001	0.0001	0.68	−0.0000	0.0000	−0.0001	0.0001	0.55
Pedestrian volume (log)	0.1653	0.2289	−0.2834	0.6140	0.47	−0.0367	0.2651	−0.5562	0.4829	0.89	−0.1576	0.2508	−0.6491	0.3339	0.53
Percent that involve alcohol	0.0163	0.0045	0.0074	0.0252	****						0.0177	0.0047	0.0085	0.0268	****

* $p<0.10$;

** $p<0.05$;

*** $p<0.01$;

**** $p<0.001$

TABLE 3

Pedestrians, SWITRS 2009–2014

	Bivariate					Model 1					Model 2				
	Est	**SE**	**95% CI**		***p***	**Est**	**SE**	**95% CI**		***p***	**Est**	**SE**	**95% CI**		***p***
All injury levels															
Class															
1	ref					ref					ref				
2	0.4050	0.2440	−0.0732	0.8831	*	0.1011	0.2882	−0.4637	0.6658	0.73	0.1660	0.2928	−0.4078	0.7398	0.57
Motor vehicle volume	0.0001	0.0000	−0.0000	0.0001	*	0.0001	0.0000	−0.0000	0.0001	0.10	0.0001	0.0000	−0.0000	0.0001	*
Pedestrian volume (log)	0.4740	0.1813	0.1188	0.8293	***	0.4034	0.2189	−0.0257	0.8325	*	0.3634	0.2207	−0.0691	0.7959	0.12
Percent that involve alcohol	0.0066	0.0054	−0.0040	0.0171	0.22						0.0057	0.0052	−0.0046	0.0159	0.28
Severe/Fatal Injuries															
Class															
1	ref					ref					ref				
2	0.1789	0.4403	−0.6841	1.0419	0.68	0.1434	0.4825	−0.8024	1.0891	0.77	0.0503	0.4149	−0.7629	0.8635	0.90
Motor vehicle volume	0.0001	0.0001	−0.0000	0.0003	*	0.0001	0.0001	−0.0000	0.0003	*	0.0000	0.0001	−0.0001	0.0001	0.91
Pedestrian volume (log)	0.3449	0.3354	−0.3124	1.0023	0.30	0.2528	0.3661	−0.4648	0.9705	0.49	0.1403	0.3203	−0.4874	0.7679	0.66
Percent that involve alcohol	0.0242	0.0045	0.0154	0.0330	****						0.0237	0.0049	0.0141	0.0333	****

* $p<0.10$;

** $p<0.05$;

*** $p<0.01$;

**** $p<0.001$