CPBS
Center for Pedestrian and Bicyclist Safety

A Tier-1 University Transportation Center

Urban Demographic Shift of Pedestrian and Bicyclist Collisions, Equity, and Police Enforcement

July 2024	A Report From the Center for Pedestrian and Bicyclist Safety

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About the Center for Pedestrian and Bicyclist Safety (CPBS)

The Center for Pedestrian and Bicyclist Safety (CPBS) is a consortium of universities committed to eliminating pedestrian and bicyclist fatalities and injuries through cutting-edge research, workforce development, technology transfer, and education. Consortium members include: The University of New Mexico; San Diego State University; The University of California Berkeley; The University of Tennessee Knoxville; and The University of Wisconsin Milwaukee. More information can be found at: https://pedbikesafety.org

Disclaimer

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16. Abstract

This study investigates the intersection of socio-economic status (SES), race/ethnicity, and the likelihood of fatal bicycle and pedestrian collisions in California. Utilizing data from multiple sources, including the California Statewide Integrated Traffic Records System (SWITRS) and the American Community Survey, we analyze how neighborhood SES influences collision outcomes across different racial/ethnic groups across California. Our findings reveal that higher SES neighborhoods generally have lower rates of fatal collisions, particularly benefiting White cyclists and pedestrians. However, Black and Hispanic individuals do not experience the same level of safety improvements, highlighting significant racial/ethnic disparities. The study identifies a lack of comprehensive infrastructure in low-income and non-White neighborhoods as a key factor contributing to higher collision rates. Additionally, dangerous driving behaviors and environmental conditions, such as driving under the influence and poor lighting, exacerbate risks in lower SES areas. We recommend targeted infrastructure investments, enhanced enforcement of traffic laws, and driver education campaigns to address these disparities. Further research is needed to explore the underlying causes of these differences and develop more effective interventions. This study aims to inform policies and practices that promote safer streets for all communities by understanding and addressing road safety's socio-economic and racial dynamics.

17. Key Words

Socioeconomic factors; Persons by race and ethnicity; Fatalities; Cyclists; Pedestrians

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APPROXIMATE CONVERSIONS TO SI UNITS

Symbol	When You Know	Multiply By	To Find	Symbol
		LENGTH		
in	inches	25.4	millimeters	mm
ft	feet	0.305	meters	m
yd	yards	0.914	meters	m
mi	miles	1.61	kilometers	km
		AREA		
in^2	square inches	645.2	square millimeters	mm^2
ft^2	square feet	0.093	square meters	m^2
yd^2	square yard	0.836	square meters	m^2
ac	acres	0.405	hectares	ha
mi^2	square miles	2.59	square kilometers	km^2
		VOLUME		
fl oz	fluid ounces	29.57	milliliters	mL
gal	gallons	3.785	liters	L
ft^3	cubic feet	0.028	cubic meters	m^3
yd^3	cubic yards	0.765	cubic meters	m^3
		NOTE: volumes greater than 1000 L shall be shown in m^3		
		MASS		
oz	ounces	28.35	grams	g
lb	pounds	0.454	kilograms	kg
T	short tons (2000 lb)	0.907	megagrams (or "metric ton")	Mg (or "t")
		TEMPERATURE (exact degrees)		
°F	Fahrenheit	5 (F-32)/9 or (F-32)/1.8	Celsius	°C
		ILLUMINATION		
fc	foot-candles	10.76	lux	lx
fl	foot-Lamberts	3.426	candela/m^2	cd/m^2
		FORCE and PRESSURE or STRESS		
lbf	poundforce	4.45	newtons	N
lbf/in^2	poundforce per square inch	6.89	kilopascals	kPa

APPROXIMATE CONVERSIONS FROM SI UNITS

Symbol	When You Know	Multiply By	To Find	Symbol
		LENGTH		
mm	millimeters	0.039	inches	in
m	meters	3.28	feet	ft
m	meters	1.09	yards	yd
km	kilometers	0.621	miles	mi
		AREA		
mm^2	square millimeters	0.0016	square inches	in^2
m^2	square meters	10.764	square feet	ft^2
m^2	square meters	1.195	square yards	yd^2
ha	hectares	2.47	acres	ac
km^2	square kilometers	0.386	square miles	mi^2
		VOLUME		
mL	milliliters	0.034	fluid ounces	fl oz
L	liters	0.264	gallons	gal
m^3	cubic meters	35.314	cubic feet	ft^3
m^3	cubic meters	1.307	cubic yards	yd^3
		MASS		
g	grams	0.035	ounces	oz
kg	kilograms	2.202	pounds	lb
Mg (or "t")	megagrams (or "metric ton")	1.103	short tons (2000 lb)	T
		TEMPERATURE (exact degrees)		
°C	Celsius	1.8C+32	Fahrenheit	°F
		ILLUMINATION		
lx	lux	0.0929	foot-candles	fc
cd/m^2	candela/m^2	0.2919	foot-Lamberts	fl
		FORCE and PRESSURE or STRESS		
N	newtons	0.225	poundforce	lbf
kPa	kilopascals	0.145	poundforce per square inch	lbf/in^2

Urban Demographic Shift of Pedestrian and Bicyclist Collisions, Equity, and Police Enforcement

A Center for Pedestrian and Bicyclist Safety Research Report

July 2024

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Acronyms, Abbreviations, and Symbols

ACS	American Community Survey
ANOVA	Analysis of Variance
EPA	Environmental Protection Agency
GLMM	Generalized Linear Mixed Model
ICC	Intraclass Correlation
SES	Socio-Economic Status
SLD	Smart Location Database
SWITRS	California Statewide Integrated Traffic Records System
VIF	Variance Inflation Factor

Abstract

This study investigates the intersection of socio-economic status (SES), race/ethnicity, and the likelihood of fatal bicycle and pedestrian collisions in California. Utilizing data from multiple sources, including the California Statewide Integrated Traffic Records System (SWITRS) and the American Community Survey, we analyze how neighborhood SES influences collision outcomes across different racial/ethnic groups across California. Our findings reveal that higher SES neighborhoods generally have lower rates of fatal collisions, particularly benefiting White cyclists and pedestrians. However, Black and Hispanic individuals do not experience the same level of safety improvements, highlighting significant racial/ethnic disparities. The study identifies a lack of comprehensive infrastructure in low-income and non-White neighborhoods as a key factor contributing to higher collision rates. Additionally, dangerous driving behaviors and environmental conditions, such as driving under the influence and poor lighting, exacerbate risks in lower SES areas. We recommend targeted infrastructure investments, enhanced enforcement of traffic laws, and driver education campaigns to address these disparities. Further research is needed to explore the underlying causes of these differences and develop more effective interventions. This study aims to inform policies and practices that promote safer streets for all communities by understanding and addressing road safety's socio-economic and racial dynamics.

Executive Summary

This study examines the critical relationship between socio-economic status (SES), race/ethnicity, and the likelihood of fatal bicycle and pedestrian collisions in California. The surge in fatal traffic accidents since 2009, particularly among pedestrians and cyclists, has raised urgent questions about road safety and the underlying socio-economic and racial disparities that influence these outcomes. This research investigates whether neighborhood SES mitigates the likelihood of fatal collisions and whether these benefits are distributed equally across different racial/ethnic groups.

The primary objectives of this study were to:

- Determine the impact of neighborhood SES on the likelihood of fatal bicycle and pedestrian collisions.
- Assess whether the benefits of higher SES neighborhoods are equally distributed across different racial/ethnic groups.
- Identify the main factors contributing to disparities in fatal collision outcomes.
- Provide actionable insights for policymakers and urban planners to address these disparities.

We used a statistical model called a generalized linear mixed model (GLMM) to achieve our research objectives. This model allowed us to consider individual characteristics (like race/ethnicity and collision circumstances) and neighborhood characteristics (like SES scores) in our analysis. We also took into account the fact that our data was collected at the neighborhood level, to ensure that the variations within neighborhoods were appropriately considered. Our data was sourced from various state databases, which provided us with comprehensive information on collision incidents, demographic details, and neighborhood socio-economic indicators. These datasets include the California Statewide Integrated Traffic Records System (SWITRS), the American Community Survey, the Caltrans Active Transportation Benefit-Cost Tool, and EPA's livability measures.

Our main results consist of the following.

- The analysis confirmed that higher neighborhood SES significantly reduces the likelihood of fatal collisions for cyclists and pedestrians. For example, each point increase in SES decreased the chance of fatal collisions by 21.1 percent for White cyclists and 22.8 percent for White pedestrians.
- Despite the overall protective effect of higher SES, the benefits were not equally distributed. Black and Hispanic cyclists and pedestrians did not experience the same level of safety improvements. Notably, SES showed no significant association with fatal collisions for Black cyclists and Asian pedestrians.

- Low-income and non-White neighborhoods often lack comprehensive pedestrian and cyclist infrastructure, such as sidewalks and bike lanes, leading to higher rates of fatal collisions. Historical underinvestment in these areas contributes to these disparities.
- Dangerous driving behaviors (e.g., driving under the influence) and hazardous environmental conditions (e.g., dark conditions) significantly increased the risk of fatal collisions across all groups. These risks were more pronounced in lower SES neighborhoods.

Higher SES neighborhoods generally provide safer environments for cyclists and pedestrians, particularly benefiting White individuals. This underscores the importance of socio-economic factors in road safety. However, the benefits of higher SES neighborhoods are not equally distributed, with Black and Hispanic populations experiencing higher risks of fatal collisions. This indicates that SES alone does not fully account for racial/ethnic disparities in collision outcomes. There is a critical need for equitable investment in pedestrian and cyclist infrastructure in low-income and non-White populations to address the higher rates of fatal collisions. To this end, we offer the following recommendations.

- Urban planners should focus on building comprehensive pedestrian and cyclist infrastructure in underserved neighborhoods to improve safety.
- Implement safety programs tailored to the specific needs of minority communities, including education on safe road practices and community engagement.
- Enhance enforcement of traffic laws, particularly in low-SES areas, to deter dangerous driving behaviors.
- Launch campaigns to educate drivers on the importance of respecting all road users, emphasizing the need to yield to pedestrians and cyclists.
- Conduct additional studies to explore the underlying causes of racial/ethnic disparities in collision outcomes and develop more effective interventions.

This study addresses road safety's socio-economic and racial dynamics, providing a foundation for creating more equitable and safer streets for all communities.

Introduction

In recent years, the surge in fatal traffic accidents has sparked significant attention and raised critical questions about road safety measures. Since 2009, pedestrian fatalities have seen a noticeable uptick (Schneider et al, 2021; GHSA, 2021). Using Fatality Analysis Reporting System (FARS) data from 2012-2021, the National Highway Traffic Safety Association (NHTSA) found that pedestrian fatalities increased by about 53% from 2012 to 2021, while cyclist fatalities increased by 32%. (NHTSA, 2023a; NHTSA, 2023b). These trends underscore the urgency of addressing road safety and highlight the disproportionate impact of such collisions on certain demographic groups.

Various studies have shown that pedestrian and bicycle collisions may be more fatal for Black and Hispanic populations (Mansfield et al., 2018; Schneider, 2020; Stoker et al., 2015) and low-income communities (Abdel-Aty et al., 2013; Apardian & Smirnov, 2020; Cottrill & Thakuriah, 2010; Guerra et al., 2019; Jermprapai & Srinivasan, 2014; Shin, 2023). However, understanding the intersection of socio-economic status (SES) with fatal collisions with respect to race/ethnicity remains a largely unexplored area of research. The local built environment and demographic factors are believed to be pivotal in shaping the severity of pedestrian and bicycle collisions. Socioeconomic status emerges as a particularly influential determinant, as it intersects with various aspects of road safety, including infrastructure, access to transportation, and community resources. However, does greater socio-economic status benefit all neighborhoods by race/ethnicity?

The present study aims to address these gaps by investigating whether neighborhood socioeconomic status mitigates the likelihood of bicycle and pedestrian collisions being fatal, with a specific focus on race/ethnicity in California. We draw upon the California Statewide Integrated Traffic Records System (SWITRS), the American Community Survey (ACS), the Caltrans Active Transportation Benefit-Cost Tool, and the Environmental Protection Agency (EPA)'s Smart Location Database (SLD) livability measures. By examining the influence of the built environment and socio-economic disparities on collision outcomes, this research sheds light on key questions: 1) Can the built environment aspects of neighborhoods alone predict the socio-economic disparities in collisions? 2) Do all racial/ethnic groups benefit equally from increases in socio-economic status within a neighborhood?

This study offers actionable insights for policymakers, urban planners, and community stakeholders through a comprehensive analysis of collision data and socio-economic indicators. By identifying the mechanisms through which socioeconomic status and race intersect with road safety outcomes, interventions can be tailored to address disparities and promote safer streets for all individuals, regardless of their socioeconomic background or racial/ethnic identity.

Literature Review

It is important to consider local demographic characteristics to understand the volume of collisions and how fatal they are. Pedestrian and cyclist injuries tend to be close to home (Anderson et al., 2012; Haas et al., 2015; Roll & McNeil, 2022; Xin et al., 2017). Half of pedestrian injuries occur within roughly a mile of the victim's home (Haas et al., 2015). How these local characteristics matter, though, is another question.

SES Leading to Poorer Environments

At one level, there is an association between SES and Racial Composition and infrastructure. Low-income and non-White pedestrians and cyclists face a substantially heightened risk of fatal collisions primarily due to the absence of safe routes in their communities (Roll, 2021; Schneider et al, 2021). Research has consistently highlighted the glaring lack of comprehensive infrastructure for pedestrians and cyclists in these areas, such as deficient sidewalk connections (Lowe, 2016; Rajaee et al., 2021) and inadequate bike lanes (Cradock et al., 2009; Braun et al, 2021).

This deficit is deeply entrenched in the broader disparities experienced by these communities. Historically, low-income and non-White neighborhoods have been grossly underinvested in terms of infrastructure due to political neglect (Gibbons and Yang 2014; Alexander, Entwisle, and Olson 2014; Sharkey 2013; Do, Frank, and Iceland 2017; Moody, Darden, and Pigozzi 2016; Gordon 2019). Lower SES minority neighborhoods often struggle to make their needs heard and addressed (Chang et al., 2009; Tigges et al., 1998). Compelling evidence substantiates that proper infrastructure is instrumental in reducing the likelihood of collisions (Hamann & Peek-Asa, 2013; Minikel, 2012; Teschke et al., 2012; Vandenbulcke et al., 2014).

In addition to the lack of resources, low-income and non-White populations are systematically exposed to environmental hazards, such as major arterial roads with high speeds and aggressive drivers (Roll, 2021). This exposure is partly due to the higher likelihood of these populations living near city centers with high vehicular activity (P.L. Jacobsen & H. Rutter, 2012). However, hazardous infrastructure construction has historically targeted low-income communities, even those far from city centers (Sugrue, 1996). In stark contrast, higher SES neighborhoods consistently enjoy superior infrastructure, encompassing well-maintained roads and dedicated bike lanes. Higher SES neighborhoods often have more resources and political clout to advocate for safety measures (Gilens & Page, 2014; Lubitow et al., 2016).

SES Affecting Drivers and Pedestrians/Victims

The socio-economic status of individual drivers has an influence on their chance of pedestrian and cyclist collisions that go beyond just the built environment. Neighborhoods with lower incomes can affect the behavior of drivers. Drivers from working-class backgrounds often have to deal with longer travel times and distances (Lee et al., 2014, 2021; Roll, 2021), leading to driver fatigue (Amoadu et al., 2023; Girotto et al., 2019; Zhou et al., 2020). This fatigue is worsened by long and irregular work hours (Amoadu et al., 2023; Gómez-Ortiz et al., 2018), job insecurity (Amoadu et al., 2023; Zhang et al., 2021), family conflicts (Amoadu et al., 2023), and driving alone (Amoadu et al., 2023; Gómez-Ortiz et al., 2018). Additionally, lower-income households are more likely to own older cars or vehicles needing repair, which increases the likelihood of crashes (Blumenberg & Haas, 2002; Cervero et al., 2002).

Lower-income areas are associated with various challenges that can contribute to negligent behavior from drivers, cyclists, and pedestrians. Studies have found more traffic violations in these neighborhoods (Lee et al., 2021), but this could be due to over-policing, leading to more citations. Pedestrians in low-income areas are less likely to observe proper safety when crossing streets (Koekemoer et al., 2017; Noland et al., 2013). This may be attributed to lower awareness of safe road navigation. Indeed, areas with higher collision rates often have lower education levels (Lin et al., 2019). Additionally, the stressors faced by low-income populations might distract them from practicing safe behaviors (Amoadu et al., 2023; Husain et al., 2019).

Race and Difference in Collisions even in high SES

More affluence in neighborhoods may not necessarily lead to demonstrative improvements for all communities, especially by race and ethnicity. For one, drivers might exhibit biased behaviors toward minority cyclists and pedestrians, leading to a higher risk of collisions. For example, drivers have been shown to act more aggressively toward pedestrians and cyclists they feel superior to (Galovski & Blanchard, 2004; McGarva & Steiner, 2000). They are less likely to yield to them or give them adequate space (Coughenour et al., 2020; Goddard et al., 2015). This aggression from some drivers in affluent neighborhoods may increase the risk of accidents.

Another issue that may affect collisions is the usage of roads and safety infrastructure. Lower-income communities and communities of color have even viewed new investment in bicycle infrastructure with suspicion, associating it with the perceived gentrification of their neighborhoods (Lubitow et al., 2016; Stein, 2011). As a consequence, they may be less likely to use this infrastructure. Also, even in more affluent neighborhoods, non-White populations may still have different commuting or travel patterns that expose them to higher traffic volumes or riskier conditions (Lee et al., 2014, 2021; Roll, 2021).

Data and Methodology

Data Sources

Several data sources were used for the analysis. Data on bicycle and pedestrian collisions were obtained from the Statewide Integrated Traffic Records System (SWITRS), a California initiative that collects information from police reports on traffic collisions within the state. Using this data, we identified our dependent variable as fatal bicycle or pedestrian collisions. SWITRS was also used to identify one of our focal predictors, the race of the pedestrian or cyclist, categorized as White (reference), Black, Hispanic, Asian, and Other. One limitation of this measure is the inability to distinguish between Hispanic and non-Hispanic individuals within these racial categories, which may affect the interpretation of our results.

We drew upon the 2015-2019 American Community Survey for our other focal predictor, census tract SES. This measure was derived from a Principal Component Analysis of median rent (loading 0.852), median home value (0.850), percent college educated (0.839), and household income (0.903). The Cronbach Alpha of these variables was 88.6 percent, indicating strong internal consistency among these variables. The resulting SES component score could explain 74.16 percent of the variance of these variables, justifying its use.

Additional collision-level predictors from the SWITRS included whether the cyclist or pedestrian was male (1 = yes, 0 = no), their age, and whether they were rear-ended. We also included whether the driver was under the influence of a controlled substance and whether the driver was driving at an unsafe speed. We also included several road condition measures from SWITRS, such as whether the collision occurred at night, whether the road was dry, and whether the weather was adverse.

Additionally, we used the Caltrans Active Transportation Benefit-Cost Tool to identify other statewide road conditions. These included whether the road was a major arterial, the speed limit for bicycle models, the presence of bicycle infrastructure, and the estimated density of cyclists on that road on a typical day. We tried to get similar density measures for pedestrians, but they were unavailable.

We also included several larger census-tract level measures. Using data from the ACS, we identified neighborhood demographics, including the percentages of Black, Hispanic, and Asian residents. We assessed neighborhoods' socio-economic status (SES) using principal component analysis to derive an SES score from median rent, median home value, percent college educated, and median household income. We include a place typology that contains seven categories: urban centers (reference), compact suburban places, suburban places, rural places, employment centers, and special districts. The place typology dataset was developed by Frost et al. (2018) and is described in the article "Quantifying the Sustainability, Livability, and Equity Performance of Urban and Suburban Places in California." The place typology was developed using a principal component analysis of six major variables: density, land mix, diversity, design, distance, and destination. The density variable included housing, population, and employment density. Land use mix refers to the employees per acre in different industries, such as entertainment and retail. Diversity encompassed building diversity (including the percentage of renter-occupied units and multi-family housing) and regional diversity. The design variable focused on street design, including intersection density and walkability. The distance variable referred to transit accessibility, while the destination variable referred to job accessibility. (Frost et al, 2018). These were included given crash risk is more likely to happen in areas with large population densities near urban centers with high employment land use (Loukaitou-Sideris et al., 2007; Merlin et al., 2020; Roll & McNeil, 2022; Xin et al., 2017). We also used a walkability score from the EPA's Smart Location Database (SLD), which calculates relative walkability by block group. According to the National Walkability Index Methodology (2021), relative walkability is determined by three main variables: intersection density, proximity to transit stops, and diversity of land uses.

Analysis

We conducted a multilevel logistic regression analysis to examine the predictors of fatal bicycle and pedestrian collisions with cars, incorporating individual and neighborhood-level characteristics. The analysis proceeded in several steps. Initially, a null model was specified to estimate the variance attributable to neighborhood-level clustering. This model included only an intercept and a random effect for the neighborhood, allowing us to assess the intraclass correlation (ICC). To check the ICC, which indicates the proportion of variance explained by the grouping structure, we used an analysis of variance (ANOVA) approach. This ICC calculation suggested that approximately 4.2 percent of the variance in fatal bicycle collisions and 6.21 percent of the variance in pedestrian collisions could be attributed to differences between neighborhoods.

We employed a generalized linear mixed model (GLMM) with a binomial distribution and a logit link function for the full model. This model included fixed effects for individual and neighborhood characteristics and a random intercept for each neighborhood-city combination to account for potential clustering at this level. The full model was fitted using the `glmer` function from the `lme4` package, with the `bobyqa` optimizer specified for better convergence. We assessed the variance inflation factor (VIF) to check for multicollinearity among the predictor variables. The models were stratified by race/ethnicity.

Results

Descriptive Results

Tables 1 and 2 present descriptive statistics for Bicycle and Pedestrian collisions stratified by the cyclist's or pedestrian's race/ethnicity. Overall, the difference in the share of fatal collisions between racial/ethnic groups is small. White cyclists have the largest share of fatal collisions, 1.5 percent (interpreting the proportion as a percentage). Meanwhile, Black cyclists have the smallest share, 1 percent. Pedestrians follow a similar trend, with White collisions having the greatest share of fatal collisions, 7.7 percent, and Black collisions having the smallest, 6.1 percent.

Table 1. Descriptive Statistics of Cycle Collisions

	White		Black		Hispanic		Asian	
	Mean	St. Dev.	Mean	St. Dev.	Mean	St. Dev.	Mean	St. Dev.
Fatal	0.015	0.120	0.010	0.101	0.014	0.117	0.013	0.113
Male	0.764	0.425	0.833	0.373	0.864	0.343	0.748	0.434
Age	39.394	18.162	34.948	17.524	31.435	16.398	35.924	19.698
Rear-Ended	0.066	0.248	0.048	0.215	0.047	0.211	0.051	0.220
Hit by Truck	0.015	0.120	0.015	0.120	0.015	0.121	0.011	0.102
Vehicle Driver Under Influence	0.010	0.101	0.008	0.089	0.010	0.101	0.005	0.069
Vehicle Driver Unsafe Speeds	0.048	0.215	0.053	0.225	0.045	0.207	0.045	0.208
Conditions Dark	0.024	0.152	0.021	0.145	0.021	0.144	0.012	0.107
Bad Weather	0.020	0.140	0.023	0.150	0.018	0.134	0.018	0.133
Major Arterial Road	0.174	0.379	0.179	0.383	0.197	0.398	0.167	0.373
Posted Speed Limit	28.073	7.793	26.798	5.870	27.177	6.478	28.051	7.445
Bicycle Infrastructure	0.217	0.412	0.147	0.354	0.122	0.327	0.251	0.434
Bicycle Density	225.437	240.418	209.025	195.340	183.486	138.586	247.956	244.766
Neighborhood Percent Black	4.422	6.017	13.522	13.897	6.042	8.357	4.360	5.800
Neighborhood Percent Asian	13.101	13.819	12.829	13.676	12.428	14.409	29.340	21.288
Neighborhood Percent Hispanic	26.681	20.417	41.623	24.377	54.444	27.335	24.436	19.748
Neighborhood SES	1.964	2.397	0.450	1.836	0.457	1.761	2.473	2.531
Compact Suburban Places	0.172	0.377	0.139	0.346	0.190	0.393	0.181	0.385
Suburban Places	0.450	0.497	0.339	0.473	0.359	0.480	0.427	0.495
Rural Places	0.054	0.226	0.010	0.098	0.014	0.119	0.028	0.164
Employment Centers	0.010	0.099	0.011	0.103	0.008	0.087	0.006	0.080
Special Districts	0.019	0.138	0.013	0.114	0.014	0.116	0.034	0.182
Walkability Score	13.230	3.489	14.218	2.702	13.940	2.676	13.767	3.126
	53,498		11,823		42,955		6,749	

As for neighborhood SES, Asian pedestrians and cyclist collisions are taking place in areas with the strongest SES scores, 2.473 and 1.844, respectively. Given that the SES score is a means-centered value of all census tracts in the state of California, Asian cyclist collisions take place in tracts with more than two standard deviations above the mean. Meanwhile, Black cyclists experience collisions in areas with comparatively smallest SES scores among cyclists, 0.450, or less than half a standard deviation above the mean, while Hispanic pedestrians experience the smallest SES scores among pedestrians, 0.223. Concerning other characteristics, there is a relatively slight variation between cyclists and pedestrians by race/ethnicity. For instance, 4.8 percent of White cyclists were struck by cars deemed by law enforcement to be driving at unsafe speeds, compared to 5.3 percent of Black cyclists. With these basic descriptive characteristics explained, we turn now to our multilevel GLMM results.

Table 2. Descriptive Statistics of Pedestrian Collisions

	White		Black		Hispanic		Asian	
	Mean	St. Dev.	Mean	St. Dev.	Mean	St. Dev.	Mean	St. Dev.
Fatal	0.077	0.266	0.061	0.238	0.065	0.247	0.063	0.243
Male	0.600	0.490	0.596	0.491	0.599	0.490	0.453	0.498
Age	42.781	20.352	37.176	19.136	34.395	20.366	47.381	23.422
Rear-Ended	0.019	0.136	0.020	0.139	0.024	0.154	0.016	0.127
Hit by Truck	0.018	0.133	0.019	0.136	0.017	0.129	0.014	0.117
Vehicle Driver Under Influence	0.022	0.146	0.017	0.129	0.024	0.153	0.014	0.119
Vehicle Driver Unsafe Speeds	0.058	0.235	0.064	0.245	0.063	0.243	0.054	0.225
Conditions Dark	0.086	0.280	0.064	0.244	0.067	0.249	0.032	0.177
Bad Weather	0.057	0.233	0.049	0.215	0.044	0.205	0.065	0.246
Major Arterial Road	0.188	0.390	0.198	0.398	0.192	0.394	0.158	0.364
Posted Speed Limit	28.041	8.382	27.231	7.486	27.491	7.744	27.180	6.850
Bicycle Infrastructure	-	-	-	-	-	-	-	-
Bicycle Density	-	-	-	-	-	-	-	-
Neighborhood Percent Black	5.300	6.615	15.982	15.838	6.668	9.196	5.091	6.448
Neighborhood Percent Asian	12.707	13.621	12.252	13.933	11.250	13.746	32.440	22.174
Neighborhood Percent Hispanic	30.628	22.098	43.298	24.264	56.845	26.622	26.586	20.565
Neighborhood SES	1.350	2.218	0.276	1.723	0.223	1.628	1.844	2.184
Compact Suburban Places	0.167	0.373	0.131	0.338	0.178	0.383	0.148	0.355
Suburban Places	0.419	0.493	0.325	0.468	0.367	0.482	0.304	0.460
Rural Places	0.043	0.203	0.010	0.101	0.024	0.152	0.010	0.102
Employment Centers	0.010	0.101	0.008	0.089	0.006	0.078	0.009	0.095
Special Districts	0.014	0.117	0.015	0.122	0.011	0.104	0.020	0.139
Walkability Score	13.656	3.326	14.153	2.643	13.753	2.820	14.662	2.719
	46,163		20,775		58,971		9,170	

GLMM Results

We begin with our focal predictors of SES, reported in Table 3; for cyclists, SES has a consistently negative association with the likelihood that a collision will be fatal, all things being equal. For example, each point of SES decreases the chance of collisions being fatal for White cyclists by 21.1 percent (1-0.789*100=21.1). Most other racial/ethnic groups measured show similar outcomes. The exception is Black collisions, where SES has no association with the chance of collisions being fatal. There is somewhat more variation in associations for SES and pedestrian collisions. For White pedestrians, each point of SES decreased the chance of the collision being fatal by 22.8 percent. Meanwhile, the chance decreased by 9.9 percent and 18.6 percent for Black and Hispanic pedestrians, respectively. There was no significant association between SES and whether Asian collisions were fatal.

Table 3. GLMM Fatal Collisions, Odds Ratios

	Bicycle				Pedestrian			
	White	Black	Hispanic	Asian	White	Black	Hispanic	Asian
	(1)	(2)	(3)	(4)	(5)	(6)	(7)	(8)
Male	1.070	1.123	1.275***	1.272***	1.144***	1.237***	1.290***	1.048
	(0.044)	(0.200)	(0.064)	(0.003)	(0.020)	(0.034)	(0.020)	(0.049)
Age	2.028***	2.260***	1.871***	2.261***	1.774***	1.735***	1.835***	2.285***
	(0.043)	(0.182)	(0.042)	(0.003)	(0.021)	(0.034)	(0.018)	(0.058)
Rear-Ended	1.173***	1.541***	1.155***	0.943***	0.831***	0.833***	0.797***	0.897*
	(0.030)	(0.113)	(0.033)	(0.004)	(0.026)	(0.039)	(0.022)	(0.052)
Hit by Truck	1.242***	1.300*	1.186***	1.403***	1.119***	1.121***	1.101***	1.158***
	(0.020)	(0.113)	(0.026)	(0.004)	(0.014)	(0.023)	(0.013)	(0.034)
Vehicle Driver Under Influence	1.308***	1.527***	1.315***	1.360***	1.181***	1.158***	1.171***	1.146***
	(0.015)	(0.083)	(0.019)	(0.004)	(0.014)	(0.023)	(0.013)	(0.037)
Vehicle Driver Unsafe Speeds	0.999	0.946	1.088*	1.277***	0.948**	0.933*	1.073***	1.018
	(0.036)	(0.124)	(0.038)	(0.004)	(0.020)	(0.035)	(0.017)	(0.048)
Conditions Dark	1.262***	1.333**	1.246***	1.277***	1.441***	1.446***	1.434***	1.342***
	(0.020)	(0.106)	(0.024)	(0.004)	(0.014)	(0.021)	(0.013)	(0.033)
Bad Weather	0.970	1.007	1.053	1.146***	0.988	0.969	1.002	1.064
	(0.043)	(0.183)	(0.036)	(0.004)	(0.020)	(0.033)	(0.018)	(0.048)
Major Arterial Road	1.098*	1.302	1.113*	1.083***	1.213***	1.253***	1.199***	1.138*
	(0.043)	(0.196)	(0.050)	(0.003)	(0.021)	(0.034)	(0.020)	(0.053)
Posted Speed Limit	1.054	1.031	1.137***	1.081***	1.192***	1.188***	1.250***	1.206***
	(0.037)	(0.197)	(0.039)	(0.003)	(0.018)	(0.026)	(0.015)	(0.045)
Bicycle Infrastructure	0.965	1.009	1.055	1.013***	-	-	-	-
	(0.047)	(0.201)	(0.050)	(0.003)	-	-	-	-
Bicycle Density	0.852*	0.659	0.751**	1.318***	-	-	-	-
	(0.078)	(0.459)	(0.092)	(0.003)	-	-	-	-
Neighborhood Percent Black	1.144**	1.224	1.184**	0.880***	1.068**	1.112*	1.050*	1.046
	(0.041)	(0.709)	(0.053)	(0.003)	(0.022)	(0.045)	(0.023)	(0.057)
Neighborhood Percent Asian	1.174***	0.868	1.039	1.063***	1.037	1.010	0.997	1.110
	(0.048)	(0.916)	(0.068)	(0.003)	(0.025)	(0.047)	(0.026)	(0.069)
Neighborhood Percent Hispanic	1.058	0.998	1.043	1.281***	1.096***	1.181**	0.989	1.171*
	(0.052)	(0.941)	(0.086)	(0.003)	(0.026)	(0.052)	(0.032)	(0.074)
Neighborhood SES	0.789***	0.943	0.764**	0.703***	0.772***	0.901*	0.814***	0.875
	(0.066)	(0.954)	(0.085)	(0.004)	(0.033)	(0.052)	(0.030)	(0.079)
Compact Suburban Places	1.085	0.935	1.184*	1.041***	1.121***	1.151***	1.149***	1.169**
	(0.066)	(0.776)	(0.067)	(0.003)	(0.028)	(0.038)	(0.025)	(0.058)
Suburban Places	1.309***	1.269	1.293***	1.392***	1.278***	1.278***	1.308***	1.368***
	(0.077)	(0.858)	(0.077)	(0.003)	(0.033)	(0.046)	(0.028)	(0.067)
Rural Places	1.165**	1.029	1.097*	0.954***	1.096***	1.018	1.085***	1.096*
	(0.055)	(0.422)	(0.041)	(0.004)	(0.025)	(0.028)	(0.019)	(0.043)
Employment Centers	1.076	1.120	1.138*	0.107***	1.010	0.979	1.000	0.995
	(0.053)	(0.702)	(0.051)	(0.004)	(0.029)	(0.041)	(0.025)	(0.068)
Special Districts	1.044	0.889	0.997	0.818***	1.057**	1.038	1.062**	1.079
	(0.049)	(0.851)	(0.059)	(0.004)	(0.021)	(0.034)	(0.019)	(0.056)
Walkability Score	0.749***	0.806	0.825**	0.642***	0.816***	0.814***	0.870***	0.852*
	(0.059)	(0.769)	(0.064)	(0.003)	(0.029)	(0.042)	(0.025)	(0.066)
Constant	0.005***	0.00002***	0.003***	0.00002***	0.047***	0.035***	0.039***	0.029***
	(0.131)	(0.784)	(0.160)	(0.003)	(0.032)	(0.057)	(0.030)	(0.117)
Observations	53,502	11,823	42,959	6,749	46,165	20,780	58,976	9,170
Log Likelihood	-3,456.486	-485.809	-2,629.996	-324.991	-10,648.220	-4,038.550	-11,950.020	-1,842.347

As for the other predictors, in some cases, some characteristics impact all racial/ethnic groups and pedestrians or cyclists. For example, across all groups, being hit by a driver under the influence increases the chance of collisions being fatal. For example, it increases the chance of fatal bicycle collisions by 30.8 percent. Also, dark conditions increase the chance of fatal collision for all groups, for example, increasing the chance of fatal collisions for Whites by 26.2 percent. In other cases, certain characteristics have different associations depending on whether the person was cycling or walking. For example, cyclists rear-ended have a greater chance of dying, while pedestrians rear-ended have less of a chance of dying. For example, White cyclists rear-ended have a 17.3 percent greater chance of dying, while those walking are 16.9 percent less likely to die.

Predicted Probabilities

We report the predicted probabilities to better understand the relationship between neighborhood SES and the chance collisions were fatal by race/ethnicity. These probabilities detail this relationship by race/ethnicity and pedestrians and cyclists. These predicted probabilities show that the chance of collisions steadily declines with the increase of neighborhood SES for each racial/ethnic group, but the decline is inconsistent. Both White pedestrians and White cyclists have the highest chance of fatal collisions in neighborhoods with the lowest SES. However, reflecting what we saw in Table 2, these odds saw the steepest drop as SES increased. Most notably, White pedestrians go from having the greatest chance of fatal collisions to a smaller chance than Black cyclists and a roughly comparable chance to Hispanic cyclists.

Figure 1. Predicted probabilities for bicycle fatalities in California by scaled SES for White, Black, Hispanic, and Asian populations.

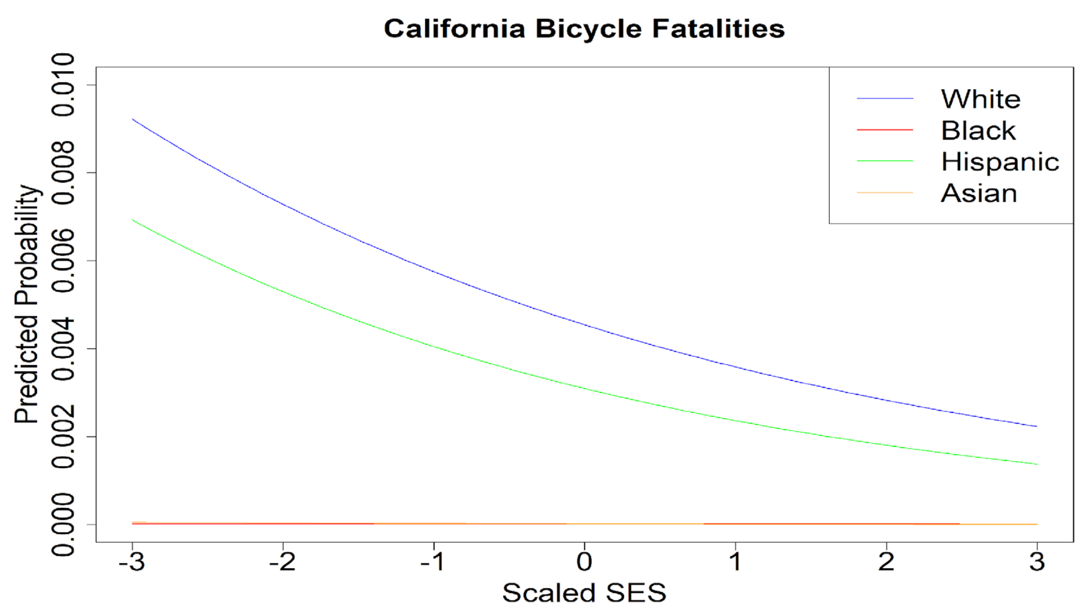
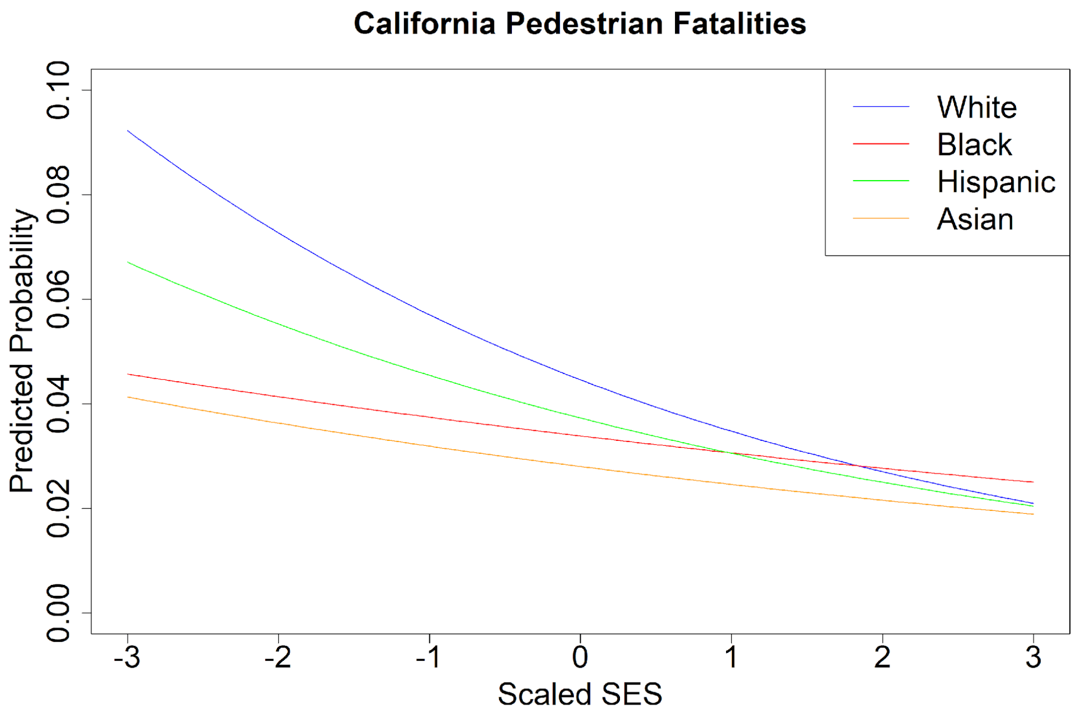


Figure 2. Predicted probabilities for pedestrian fatalities in California by scaled SES for White, Black, Hispanic, and Asian populations.


California Pedestrian Fatalities
Predicted Probability
0.00
0.02
0.04
0.06
0.08
0.10
-3
-2
-1
0
1
2
3
Scaled SES
White
Black
Hispanic
Asian

Discussion

The results of our study reveal critical insights into the relationship between socio-economic status (SES), race/ethnicity, and the likelihood of bicycle and pedestrian collisions being fatal. These findings have implications for road safety policies and urban planning, particularly in addressing the persistent disparities in collision outcomes among racial/ethnic groups. The study's key findings are discussed below.

Our analysis shows that neighborhood SES has a significant impact on the likelihood of fatal collisions for cyclists and pedestrians, but this impact is not uniform across racial/ethnic groups. Higher SES is generally associated with a reduced likelihood of fatal collisions, supporting the view that wealthier neighborhoods provide safer environments for cyclists and pedestrians. This trend, however, is less pronounced for Black and Hispanic pedestrians and cyclists, and notably, SES showed no significant association with fatal collisions for Black cyclists and Asian pedestrians. These findings underscore the complex interplay between SES and race/ethnicity in influencing road safety outcomes.

It is difficult to say why this is the case with this analysis. These disparities cannot be reduced to the built environment or other demographic factors, as we control for those in our models. One possibility is that subtle interracial tensions can remain in high-income neighborhoods. On the one hand, this could be reflected in higher-income drivers being less likely to yield or be mindful of pedestrians they feel are beneath them, such as racial/ethnic minorities (Coughenour et al., 2020; Galovski & Blanchard, 2004; Goddard et al., 2015; McGarva & Steiner, 2000). This could also be reflected by the distrust racial minorities have of infrastructure in these communities, feeling it is not 'for them' (Lubitow et al., 2016; Stein, 2011). It is also possible that communing patterns differ by race/ethnicity, leading to different opportunities for potentially fatal collisions (Lee et al., 2014, 2021; Roll, 2021). This could also reflect that urban planning and policies in affluent areas might not consider the specific needs and patterns of minority cyclists and pedestrians, leading to less safe infrastructure. These results could also reflect the fact that there are fewer Black and Hispanic cyclists and pedestrians in more affluent areas in California. We cannot confirm this possibility as we could not parse out bicycle and pedestrian activity based on race/ethnicity statewide. These possibilities should be explored more thoroughly in future research. In short, we can surmise based on these results that neighborhood SES may not trickle down to individuals by race the same way.

In addition to the findings about SES and fatal collisions, our results also say much about the variability of race/ethnicity and the fatality of collisions. The descriptive statistics highlight that overall, White cyclists and pedestrians have the greatest share of fatal collisions. However, our models make clear that this disparity can mostly be accounted for by the built environment and demographic characteristics. This demonstrates that great investment in the built environment can improve conditions, though how well it carries across different racial and ethnic groups.

While our models specifically control the presence of built environments across racial/ethnic groups, they do not speak to the overall presence of these resources in neighborhoods regardless of whether their residents have experienced a collision. It is also worth noting that low-income and non-White neighborhoods often lack comprehensive pedestrian and cyclist infrastructure, such as sidewalks and bike lanes, which are crucial for reducing collision risks. The historical underinvestment in infrastructure in these neighborhoods, compounded by political neglect, contributes to the higher rates of fatal collisions observed among these populations. However, our results built onto this by making clear that residing within more affluent neighborhoods where these resources can be assumed does not lead to an equitable improvement of conditions for all racial/ethnic groups equally.

The study further reveals that certain neighborhood characteristics, such as being struck by a driver under the influence or in dark conditions, increase the risk of fatal collisions across all racial/ethnic groups. However, the impact of these factors is exacerbated in lower SES neighborhoods. Drivers in these areas often face longer travel times, driver fatigue, and vehicle-related issues, increasing the likelihood of collisions.

Conclusions and Recommendations

Our study confirms that higher neighborhood SES is generally associated with a reduced likelihood of fatal bicycle and pedestrian collisions. This indicates that affluent areas provide safer environments due to better infrastructure and resources. Despite the overall protective effect of higher SES, this protective effect is strongest for White cyclists and pedestrians. Black and Hispanic cyclists and pedestrians do not experience the same level of safety benefits as their White counterparts. This suggests that factors beyond neighborhood SES, such as biased driver behaviors and differential use of infrastructure, play significant roles in the disparity of fatal collision outcomes.

In addition to these findings, we also find that the lack of comprehensive pedestrian and cyclist infrastructure contributes to higher rates of fatal collisions. These areas suffer from historical underinvestment, leading to inadequate safety measures and higher exposure to traffic hazards. Also, dangerous driving behaviors and hazardous environmental conditions, such as driving under the influence and dark conditions, significantly increase the risk of fatal collisions across all racial/ethnic groups. However, these risks are exacerbated in lower SES neighborhoods where such dangerous conditions are more prevalent. Our results suggest minority pedestrians and cyclists face risks of fatal collisions due to aggressive driver behavior in affluent neighborhoods. This points to the need for interventions that address not only physical infrastructure but also driver education and enforcement of traffic laws.

Based on our analysis, we make the following recommendations to policymakers.

1. Equitable Infrastructure Investment. Policymakers and urban planners should prioritize equitable pedestrian and cyclist infrastructure investment, especially in low-income and non-White neighborhoods. This includes building comprehensive pedestrian and cyclist infrastructure investment, sidewalk networks, bike lanes, and safe crossing points to reduce collision risks.

2. Targeted Safety Programs. Implement targeted road safety programs that address the specific needs of minority populations. These programs should include education on road safety practices, community engagement to increase the use of new infrastructure, and initiatives to reduce aggressive driver behavior towards minority pedestrians and cyclists.

3. Driver Education Campaigns. Launch driver education campaigns that promote respect and safety for all road users, regardless of race/ethnicity. These campaigns should highlight the importance of yielding to pedestrians and cyclists and maintaining safe distances.

4. Further Research and Data Collection. Conduct further research to understand the underlying causes of racial/ethnic disparities in fatal collision outcomes. This should include qualitative studies on community perceptions of new infrastructure and quantitative analysis of driver behaviors in different SES contexts. Future research would also benefit from knowing the racial

and socio-economic breakdown of who is walking and bicycling so we can better understand exposure rates.

5. Policy Integration. Integrate this study's findings into state and local transportation policies and standards. Update specifications, procedures, and techniques to reflect the need for equitable safety measures and targeted interventions based on SES and racial/ethnic disparities.

By implementing these recommendations, we can move towards a more equitable and safer transportation system that protects all road users, regardless of their socio-economic background or racial/ethnic identity.

This study highlights the nuanced and multifaceted relationship between SES, race/ethnicity, and road safety. While higher SES neighborhoods generally provide safer environments for cyclists and pedestrians, these benefits are not equally distributed among all racial/ethnic groups. This underscores the need for targeted interventions that address the specific needs and challenges faced by minority communities, particularly in lower SES areas. Policymakers and urban planners must prioritize equitable investment in infrastructure and consider the socio-economic and racial dynamics at play to effectively reduce the disparities in fatal collision outcomes and promote safer streets for all residents.

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