CPBS
Center for Pedestrian and Bicyclist Safety

A Tier-1 University Transportation Center

Unequal Protection: Race, Socioeconomic Status, and the Geography of Fatal Pedestrian and Bicyclist Collisions in California

July 2025

A Report From the Center for Pedestrian and Bicyclist Safety

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16. Abstract

This study investigates the persistent racial and socioeconomic disparities in fatal pedestrian and bicycle collisions across California. Leveraging a rich dataset the authors explore whether neighborhood socio-economic status (SES) mitigates fatality risk and whether this protective effect extends equally across racial and ethnic groups. Using generalized linear mixed models (GLMMs), the analysis controls for a range of built environment features, road conditions, and demographic characteristics to isolate the impact of SES and race/ethnicity on collision outcomes. The results reveal that while higher neighborhood SES is generally associated with reduced risk of fatal collisions, this benefit is disproportionately realized by White cyclists and pedestrians. In contrast, Black and Hispanic individuals do not experience comparable improvements in safety, and for some groups, such as Black cyclists and Asian pedestrians, SES has no statistically significant protective effect.

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SI* (MODERN METRIC) CONVERSION FACTORS				
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)		
^oF	Fahrenheit	5 (F-32)/9 or (F-32)/1.8	Celsius	^oC
		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)		
^oC	Celsius	1.8C+32	Fahrenheit	^oF
		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

Unequal Protection: Race, Socioeconomic Status, and the Geography of Fatal Pedestrian and Bicyclist Collisions in California

A Center for Pedestrian and Bicyclist Safety Research Report

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Acronyms, Abbreviations, and Symbols

ACS	American Community Survey
BIPOC	Black, Indigenous, and People of Color
CALTRANS	California Department of Transportation
DOT	Department of Transportation
EPA	Environmental Protection Agency
GLMM	Generalized Linear Mixed Model
GIS	Geographic Information Systems
LOS	Level of Service
MPO	Metropolitan Planning Organization
OR	Odds Ratio
POC	People of Color
PCA	Principal Component Analysis
SES	Socio-Economic Status
SWITRS	Statewide Integrated Traffic Records System (California)
USDOT	United States Department of Transportation

Abstract

This study investigates the persistent racial and socioeconomic disparities in fatal pedestrian and bicycle collisions across California, addressing an urgent public safety issue linked to rising fatality rates among vulnerable road users. Leveraging a rich dataset compiled from the California Statewide Integrated Traffic Records System (SWITRS), American Community Survey (ACS), Caltrans Active Transportation Benefit-Cost Tool, and the EPA's Smart Location Database, the authors explore whether neighborhood socio-economic status (SES) mitigates fatality risk and whether this protective effect extends equally across racial and ethnic groups. Using generalized linear mixed models (GLMMs), the analysis controls for a range of built environment features, road conditions, and demographic characteristics to isolate the impact of SES and race/ethnicity on collision outcomes. The results reveal that while higher neighborhood SES is generally associated with reduced risk of fatal collisions, this benefit is disproportionately realized by White cyclists and pedestrians. In contrast, Black and Hispanic individuals do not experience comparable improvements in safety, and for some groups, such as Black cyclists and Asian pedestrians, SES has no statistically significant protective effect. These findings persist even after adjusting for traffic infrastructure, road type, and driver behavior, suggesting that structural racism and unequal resource utilization may undermine the safety benefits typically attributed to higher SES environments. Through statistical analysis of over a decade of collision data, this study underscores the need for targeted, equity-driven interventions in transportation planning, such as inclusive infrastructure investments, community-engaged safety programs, and driver behavior reforms, to address the intersectional risks faced by people of color in both low- and high-SES areas.

Executive Summary

This study responds to the troubling rise in pedestrian and bicyclist fatalities in the United States, particularly among communities of color, by examining how racial and socioeconomic disparities shape fatal collision outcomes across California. Drawing from a growing body of research that highlights elevated collision risks for Black and Hispanic individuals, especially in low-income neighborhoods, the project goes beyond prior work by investigating whether these disparities persist after controlling for built environment features, individual-level demographics, and neighborhood socio-economic status (SES). The core objective is to determine whether higher SES environments reduce the likelihood of fatal collisions equally across racial and ethnic groups and to identify the social mechanisms that underpin unequal road safety outcomes.

The research employs a multi-method approach combining rigorous statistical modeling. Bicycle and pedestrian collision data were collected from the California Statewide Integrated Traffic Records System (SWITRS), covering the period from 2011 to 2022. These data were augmented with demographic information from the American Community Survey (ACS), police enforcement indicators, built environment measures from Caltrans and OpenStreetMap, and walkability scores from the EPA's Smart Location Database. A place typology based on land use and urban design characteristics was also used to classify neighborhood context. This rich, multi-sourced dataset enabled the researchers to assess the relationship between race, SES, and fatality risk while accounting for traffic infrastructure, road conditions, and neighborhood form.

The analysis centers on generalized linear mixed models (GLMMs), stratified by race/ethnicity and crash type (bicyclist or pedestrian), to examine whether SES mitigates the probability of fatality in collisions involving vehicles. The models control for a wide range of covariates, including age, gender, time of day, road type, vehicle speed, driver behavior (e.g., intoxication), and location-based characteristics like walkability and land use density. A multilevel framework was used to incorporate neighborhood clustering effects.

The key findings reveal a complex and uneven relationship between SES, race/ethnicity, and fatal crash outcomes. While increases in neighborhood SES are generally associated with decreased fatality risk for White cyclists and pedestrians, the benefits of affluent environments are not equally distributed. Notably, Black cyclists experience no statistically significant reduction in fatality risk with higher SES, and Asian pedestrians similarly do not benefit from safer conditions in more affluent areas. For Hispanic pedestrians, the risk declines modestly, but the protective effects are still less than those seen for White counterparts. These results persist even after controlling for road conditions, infrastructure availability, and enforcement-related variables, indicating that structural and behavioral factors may undermine the protective benefits of SES for communities of color.

The analysis further reveals that collisions involving POC often occur in areas lacking adequate infrastructure, such as bike lanes and crosswalks, and are more likely to happen on high-speed arterials. Although affluent neighborhoods tend to have better infrastructure, racial disparities persist within them, suggesting that the presence of infrastructure alone is insufficient to ensure equitable safety outcomes. This could be due to a variety of mechanisms, including discriminatory driver behavior (e.g., drivers failing to yield to non-White pedestrians), mistrust or underutilization of new infrastructure in gentrifying areas, or differences in commuting patterns and exposure to traffic risks across racial groups.

The study concludes that addressing disparities in road safety requires more than investment in infrastructure. While improving the built environment is essential, such interventions must be paired with equity-focused strategies that consider how different groups experience and access those improvements. Key recommendations include: prioritizing infrastructure investment in low-SES and majority-minority neighborhoods; implementing targeted road safety programs that engage local communities; and promoting educational campaigns to counteract driver bias and encourage safer, more inclusive road behaviors. Finally, transportation policy and planning practices must reckon with the legacy of disinvestment and structural racism that continues to shape who is safe, and who is not, on American streets.

By rigorously analyzing the intersection of race, class, and the built environment in relation to fatal pedestrian and bicyclist collisions, this project offers a nuanced understanding of where and for whom road safety improvements are working, and where they are not. The study highlights the importance of disaggregated, spatially aware, and justice-oriented transportation research and provides a strong empirical foundation for the development of more equitable and effective traffic safety interventions.

Introduction

In the past decade, a troubling trend has emerged on American roadways: a steady and significant increase in pedestrian and bicyclist fatalities (Schneider et al., 2021). According to data from the National Highway Traffic Safety Administration (NHTSA), pedestrian deaths rose by over 50 percent between 2012 and 2021, while bicyclist fatalities increased by more than 30 percent over the same period (National Highway Traffic Safety Administration, 2023a, 2023b). These statistics stand in sharp contrast to broader improvements in automotive safety and signal an urgent need to reassess the equity and effectiveness of traffic safety planning and infrastructure development. Particularly concerning is the mounting evidence that these fatalities are not evenly distributed across the population. Instead, they disproportionately impact people of color (POC), especially Black and Hispanic pedestrians and cyclists (Glassbrenner et al., 2022; Mansfield et al., 2018; Schneider, 2020; Stoker et al., 2015), who often live in neighborhoods historically shaped by racial segregation, economic disinvestment, and substandard infrastructure (CITE).

This research project directly engages with this public safety crisis by addressing two interrelated questions: First, do racial and ethnic disparities in fatal bicycle and pedestrian collisions persist even after accounting for neighborhood-level socio-economic status (SES) and other demographic and environmental factors? Second, how do the spatial and temporal patterns of these fatalities reflect broader structural inequities in the built environment and enforcement practices? By exploring these questions, the study builds upon existing literature that has identified race and class as key predictors of traffic-related injury and death, while moving beyond surface-level correlations to investigate the structural mechanisms that drive persistent inequities.

Despite the well-documented link between infrastructure inequality and road safety outcomes, relatively little research has explored whether improvements in socio-economic conditions, such as living in higher-income neighborhoods, provide equal safety benefits to residents across racial and ethnic groups. Do POC living in affluent areas experience the same reduction in risk as their White peers, or do structural and behavioral factors continue to place them at elevated danger? This question is crucial for understanding whether existing transportation equity initiatives, which often focus on place-based infrastructure upgrades, are sufficient to reduce disparities or whether they must be supplemented by targeted programs that address racialized social dynamics and behavioral factors.

To address this gap, this project employs a robust, multi-source dataset combining collision records, demographic data, built environment measures, and enforcement indicators. The primary source of collision data comes from the California Statewide Integrated Traffic Records System (SWITRS), which provides detailed information on pedestrian and bicycle crashes reported to law enforcement between 2011 and 2022. These data are linked to demographic and socio-economic indicators from the American Community Survey (ACS), which allow for the construction of a composite SES measure based on neighborhood-level income, education, rent, and home values. Additional context is provided through police enforcement data, road condition and infrastructure indicators from Caltrans and OpenStreetMap, and walkability scores derived from the EPA's Smart Location Database.

By applying generalized linear mixed models (GLMMs) to this integrated dataset, the study is able to assess whether SES independently predicts the likelihood of fatality in a collision and, crucially, whether that relationship is moderated by race and ethnicity. This analytical approach enables the researchers to isolate the effects of SES from those of race, infrastructure, enforcement, and neighborhood form, thereby providing a clearer understanding of how each of these variables contributes to fatality risk. The stratification of models by race and ethnicity also allows for a more granular exploration of group-specific dynamics, revealing whether presumed safety benefits of higher SES environments extend to all residents or remain unequally distributed.

This project also contributes methodologically by combining multilevel modeling to examine where and for whom fatal collisions occur. These methods not only inform public policy and urban planning efforts but also challenge the notion that universal infrastructure improvements are sufficient to achieve equity. Instead, they point to the need for intentional, community-specific approaches that recognize the intersectionality of race, place, and class in shaping transportation risk.

In sum, this research aims to provide a comprehensive, empirically grounded understanding of how socio-economic and racial disparities manifest in pedestrian and bicyclist fatalities. It advances the literature by testing whether higher-income neighborhoods offer universal protection or reinforce existing inequalities; by integrating police, demographic, and environmental data into a unified analytical framework; and by identifying the spatial dimensions of fatality risk across time. In doing so, it generates actionable insights for policymakers, urban planners, and advocates seeking to create safer and more equitable streets for all road users, regardless of race or economic status. Ultimately, the study demonstrates that tackling racial disparities in traffic fatalities requires not just better infrastructure, but also systemic changes in how transportation systems are planned, policed, and experienced across communities.

Literature Review

Understanding the relationship between socio-economic status (SES), race/ethnicity, and fatal pedestrian and bicycle collisions is complex and multifaceted. Prior research has consistently shown that fatal collisions are more likely to occur in communities with lower SES, and that racial and ethnic minorities, particularly Black and Hispanic individuals, are disproportionately affected by these incidents. However, much of the existing literature has examined these factors in isolation, without fully exploring how SES and race/ethnicity interact with each other and with the built environment to influence fatality risk.

One key factor that contributes to these disparities is the built environment. Low-income and majority-non-White neighborhoods are often marked by insufficient infrastructure for safe walking and cycling. These areas frequently lack continuous sidewalks, bike lanes, safe crossing points, and effective traffic-calming measures (Braun et al., 2019; Cradock et al., 2009; Lowe, 2016; Rajaee et al., 2021). Numerous studies confirm that high-quality infrastructure is crucial for reducing the likelihood and severity of bicycle and pedestrian collisions (Hamann & Peek-Asa, 2013; Minikel, 2012; Teschke et al., 2012; Vandenbulcke et al., 2014). The absence of such protections leaves cyclists and pedestrians, especially those in low-SES communities, at greater risk.

Historical and systemic disinvestment in infrastructure has exacerbated these disparities. Due to long-standing patterns of racial segregation and political marginalization, communities of color have often received fewer resources and infrastructure upgrades compared to wealthier, predominantly White neighborhoods (Alexander et al., 2014; Do et al., 2017; Gibbons & Yang, 2014; Gordon, 2019; Moody et al., 2016; Sharkey, 2013). These same communities frequently face difficulties in having their concerns addressed through formal planning processes (Chang et al., 2009; Tigges et al., 1998). In contrast, more affluent neighborhoods not only tend to have better-maintained roads and pedestrian facilities, but also greater political influence to advocate for safety improvements (Gilens & Page, 2014; Lubitow et al., 2016).

Environmental hazards also play a major role in shaping fatality risk. Low-income and non-White residents are more likely to live near high-speed arterials and major thoroughfares, increasing their exposure to traffic dangers (P.L. Jacobsen & H. Rutter, 2012; Roll, 2021; Sanders & Schneider, 2022). Historically, urban highways and hazardous road projects have often been routed through minority neighborhoods, further compounding the risk (Self, 2003; Sugrue, 1996).

Beyond the built environment, the socio-economic characteristics of drivers and local conditions can affect collision risks. Drivers from lower-income backgrounds may face longer commutes, irregular work hours, and vehicle-related issues such as older or poorly maintained cars, factors linked to driver fatigue and unsafe driving behaviors
(Amoadu et al., 2023; Blumenberg & Haas, 2002; Cervero et al., 2002; Girotto et al., 2019; Gómez-Ortiz et al., 2018; Lee et al., 2014, 2021; Zhou et al., 2020). These challenges, combined

with stress and job insecurity, may contribute to more hazardous road environments in disadvantaged areas.

Low-income areas may also see different patterns of behavior among both drivers and pedestrians. For example, higher traffic violation rates have been observed in these neighborhoods (Lee et al., 2021), though this may reflect not only reckless driving but also increased police presence and enforcement. Additionally, pedestrians in these areas may have less access to traffic safety education and may be forced to navigate poorly designed or maintained streets, increasing their vulnerability (Husain et al., 2019; Koekemoer et al., 2017; Noland et al., 2013).

Yet, even higher-SES neighborhoods may not be equally safe for all. Research suggests that racial bias influences driver behavior, non-White pedestrians are less likely to be yielded to at crosswalks, particularly in affluent areas and by drivers of more expensive vehicles (Coughenour et al., 2020; Goddard et al., 2015). This may explain why increased neighborhood affluence does not uniformly reduce fatality risk for all racial and ethnic groups.

Furthermore, cultural and political perceptions of infrastructure may shape how resources are used. In some communities of color, new cycling infrastructure has been viewed with suspicion and associated with gentrification or displacement (Lubitow et al., 2016; Stein, 2011), leading to lower utilization rates. Commuting patterns may also vary by race and ethnicity, with some groups facing greater exposure to high-risk environments regardless of neighborhood affluence (Lee et al., 2014, 2021; Roll, 2021).

In sum, while prior studies have established that SES and race/ethnicity are important predictors of pedestrian and bicyclist fatalities, less is known about how these variables interact, especially when factoring in built environment quality and behavioral dynamics. This study addresses that gap by investigating whether higher neighborhood SES leads to improved safety outcomes for all racial and ethnic groups, or whether disparities persist despite improvements in socio-economic context. By linking individual, neighborhood, and structural factors, this research offers a more comprehensive understanding of the mechanisms driving inequitable road safety outcomes.

Data and Methodology

This study investigates the intersection of race, socio-economic status (SES), and fatal pedestrian and bicyclist collisions across California, with the goal of determining whether disparities in fatality outcomes persist after controlling for neighborhood and individual-level factors. The analysis integrates multiple data sources spanning demographic, infrastructural, and enforcement-related indicators, and employs multilevel statistical models to evaluate both individual and contextual influences on collision outcomes.

Data Sources

The primary data on pedestrian and bicyclist collisions were obtained from the California Statewide Integrated Traffic Records System (SWITRS), covering incidents reported between 2011 and 2022. SWITRS includes detailed information on the nature of each crash, the individuals involved, vehicle characteristics, contributing factors, and environmental conditions. For the purposes of this study, the dependent variable is a binary indicator of whether a collision involving a pedestrian or bicyclist resulted in a fatality. Race/ethnicity of the pedestrian or cyclist was extracted from SWITRS and categorized as White (reference group), Black, Hispanic, Asian, or Other. While these categories reflect commonly used racial designations, a notable limitation is the inability to disaggregate non-Hispanic from Hispanic individuals within each racial category. Additionally, multiracial individuals are grouped under "Other," which limits interpretive specificity.

Neighborhood socio-economic characteristics were drawn from the American Community Survey (ACS) 2015–2019 five-year estimates, joined to SWITRS data at the census tract level. SES was operationalized using principal component analysis (PCA) on four tract-level variables: median rent, median home value, percentage of residents with a college degree, and median household income. These indicators were standardized prior to PCA, and the resulting SES score captured over 74% of the total variance. The SES index demonstrated high internal reliability (Cronbach's Alpha = 0.886) and was used as a continuous predictor in the models.

To capture the influence of the built environment and road context, several additional data sources were integrated. Bicycle infrastructure presence and cyclist density estimates were obtained using the PeopleForBikes Bicycle Network Analysis tool and OpenStreetMap layers, which were processed via the Caltrans Active Transportation Benefit-Cost Tool. Road classification (e.g., arterial vs. local street), posted speed limit, weather, and time-of-day information were included as covariates from SWITRS. A walkability score, derived from the EPA's Smart Location Database (SLD), was included to reflect relative pedestrian accessibility based on intersection density, proximity to transit, and land use diversity.

Neighborhood typology was classified using a place-type framework developed by Frost et al. (2018), which incorporates six urban form dimensions: density, land mix, design, diversity, destination accessibility, and transit proximity. Tracts were categorized as urban centers, urban places, compact suburban, suburban, rural, employment centers, or special districts.

Modeling Strategy and Statistical Methods

The primary analytical technique employed was generalized linear mixed modeling (GLMM) using a binomial distribution and logit link function to estimate the likelihood of fatality in a pedestrian or bicycle collision. Models were stratified by race/ethnicity to assess differential effects of SES and environmental conditions across groups. Both individual-level and neighborhood-level covariates were included, with census tracts nested within cities treated as a random intercept to account for spatial clustering and unobserved contextual variation.

All models were implemented in R (version 4.2+) using the `lme4` package. The `glmer()` function was used to estimate the fixed and random effects, and the 'bobyqa' optimizer was specified to enhance convergence stability. Multicollinearity was assessed using variance inflation factors (VIFs), which confirmed acceptable tolerance thresholds for all included predictors. To evaluate the extent of between-neighborhood variation in fatality outcomes, intraclass correlation coefficients (ICCs) were calculated from null models (i.e., random intercept-only models). ICC values were approximately 4.2% for bicyclist collisions and 6.2% for pedestrian collisions, indicating modest but meaningful clustering at the neighborhood level.

Data Treatment and Assumptions

Only cases with complete information on key variables (e.g., fatality outcome, SES, race/ethnicity, location) were included in the final analytic sample. Collisions involving multiple pedestrians or cyclists were disaggregated to person-level records. To mitigate potential bias from geographic exposure, pedestrian and cyclist density measures were included where available, although pedestrian exposure data by race were not obtainable and are acknowledged as a study limitation. The analysis assumes that fatality risk is conditioned by both observable characteristics (e.g., infrastructure, behavior) and latent contextual influences (e.g., systemic disinvestment, structural racism) that are partially captured through neighborhood typologies and SES proxies. Sensitivity tests using alternative SES measures (e.g., raw income or educational attainment alone) produced substantively similar results, supporting the robustness of the PCA-based SES index.

Results

This section presents findings from a series of multilevel generalized linear mixed models (GLMMs) estimating the likelihood that a pedestrian or bicyclist collision results in a fatality, with attention to how this risk varies by the race/ethnicity of the victim and the socio-economic status (SES) of the neighborhood where the collision occurs. The analysis proceeds from descriptive statistics to regression estimates and predicted probabilities to demonstrate how SES moderates fatality risk, and how that moderation differs across racial and ethnic groups.

Descriptive statistics, reported in Tables 1 and 2, reveal important contextual differences in where fatal collisions occur. On average, Black and Hispanic pedestrians and cyclists involved in fatal collisions reside in neighborhoods with significantly lower SES scores compared to White and Asian individuals. For instance, the mean SES score of neighborhoods where Black cyclists are killed is nearly two standard deviations below the state average, highlighting how structural conditions vary sharply by race. Meanwhile, collisions involving White individuals span a broader SES range, with many occurring in relatively affluent areas.

Table 1. Descriptive Statistics of Cycle Collisions in California 2011-2022, by Race/Ethnicity

	White		Black		Hispanic		Asian	
	Mean	St. Dev.	Mean	St. Dev.	Mean	St. Dev.	Mean	St. Dev.
Fatal^{D}	0.015	0.120	0.010	0.101	0.014^{NS}	0.117	0.013^{NS}	0.113
Male^{D}	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^{D}	0.066	0.248	0.048	0.215	0.047	0.211	0.051	0.220
Hit by Truck^{D}	0.015	0.120	0.015^{NS}	0.120	0.015^{NS}	0.121	0.011	0.102
Vehicle Driver Under Influence^{D}	0.010	0.101	0.008	0.089	0.010^{NS}	0.101	0.005	0.069
Vehicle Driver Unsafe Speeds^{D}	0.048	0.215	0.053	0.225	0.045	0.207	0.045^{NS}	0.208
Conditions Dark^{D}	0.024	0.152	0.021^{NS}	0.145	0.021	0.144	0.012	0.107
Bad Weather^{D}	0.020	0.140	0.023	0.150	0.018	0.134	0.018^{NS}	0.133
Major Arterial Road^{D}	0.174	0.379	0.179^{NS}	0.383	0.197	0.398	0.167^{NS}	0.373
Posted Speed Limit	28.073	7.793	26.798	5.870	27.177	6.478	28.051^{NS}	7.445
Bicycle Infrastructure^{D}	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^{NS}	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^{D}	0.172	0.377	0.139	0.346	0.190	0.393	0.181	0.385
Suburban Places^{D}	0.450	0.497	0.339	0.473	0.359	0.480	0.427	0.495
Rural Places^{D}	0.054	0.226	0.010	0.098	0.014	0.119	0.028	0.164
Employment Centers^{D}	0.010	0.099	0.011^{NS}	0.103	0.008	0.087	0.006	0.080
Special Districts^{D}	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	

Note: All differences in means between White and non-White means are significant (*p<0.050) unless otherwise indicated (^{NS}); Values of ^{D} indicate dichotomous variables.

Table 2. Descriptive Statistics of Pedestrian Collisions in California 2011-2022, by Race/Ethnicity

	White		Black		Hispanic		Asian	
	Mean	St. Dev.	Mean	St. Dev.	Mean	St. Dev.	Mean	St. Dev.
Fatal^{D}	0.077	0.266	0.061	0.238	0.065	0.247	0.063	0.243
Male^{D}	0.600	0.490	0.596^{NS}	0.491	0.599^{NS}	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^{D}	0.019	0.136	0.020^{NS}	0.139	0.024	0.154	0.016	0.127
Hit by Truck^{D}	0.018	0.133	0.019^{NS}	0.136	0.017^{NS}	0.129	0.014	0.117
Vehicle Driver Under Influence^{D}	0.022	0.146	0.017	0.129	0.024	0.153	0.014	0.119
Vehicle Driver Unsafe Speeds^{D}	0.058	0.235	0.064	0.245	0.063	0.243	0.054	0.225
Conditions Dark^{D}	0.086	0.280	0.064	0.244	0.067	0.249	0.032	0.177
Bad Weather^{D}	0.057	0.233	0.049	0.215	0.044	0.205	0.065	0.246
Major Arterial Road^{D}	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
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^{D}	0.167	0.373	0.131	0.338	0.178	0.383	0.148	0.355
Suburban Places^{D}	0.419	0.493	0.325	0.468	0.367	0.482	0.304	0.460
Rural Places^{D}	0.043	0.203	0.010	0.101	0.024	0.152	0.010	0.102
Employment Centers^{D}	0.010	0.101	0.008	0.089	0.006	0.078	0.009^{NS}	0.095
Special Districts^{D}	0.014	0.117	0.015^{NS}	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	

Note: All differences in means between White and non-White means are significant (*p<0.050) unless otherwise indicated (^{NS}); Values of ^{D} indicate dichotomous variables.

The multilevel regression models, reported in Table 3, show that SES is a strong and statistically significant predictor of fatality for most racial and ethnic groups, but not all. For White cyclists, each one-unit increase in neighborhood SES is associated with a 21.1 percent decrease in the odds of a fatal collision, holding all other factors constant. This is reflected in an odds ratio (OR) of approximately 0.79, where values below 1.0 indicate a reduced likelihood of a fatal outcome as SES increases. Similarly, for White pedestrians, the odds ratio is around 0.78, suggesting a slightly stronger protective effect of neighborhood affluence.

The models also reveal a protective effect for Hispanic individuals, though to a lesser extent. Hispanic cyclists experience a 23.6 percent reduction in the odds of a fatal collision with each unit increase in SES, while Hispanic pedestrians experience an 18.6 percent reduction. While these patterns are broadly consistent with those seen for White individuals, the magnitude and precision of the effect are somewhat smaller, as reflected in wider confidence intervals and lower statistical significance.

Crucially, the protective role of SES is much weaker, and in some cases absent, for Black and Asian individuals. For Black cyclists, there is no statistically significant association between neighborhood SES and the probability of a fatal outcome. The odds ratio in this case hovers near 1.0, indicating that residing in a higher-SES area does not reduce their risk of a fatal collision. Black pedestrians do show a modest reduction in risk, with an odds ratio near 0.90, but this effect is smaller and statistically marginal. For Asian pedestrians, SES likewise does not predict fatality risk in a statistically meaningful way.

Table 3. GLMM Fatal Collisions in California 2011-2022, 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

Notes: *p<0.050; **p<0.010; ***p<0.001; Predictors Scaled

These findings suggest that while neighborhood affluence offers some protection against fatal collisions, the magnitude and consistency of that protection vary substantially by race and ethnicity. The benefit of higher-SES neighborhoods is most clearly observed among White individuals, somewhat attenuated among Hispanic individuals, and largely absent among Black and Asian individuals. This undermines any assumption that improvements in neighborhood SES uniformly translate into safety for all road users.

Beyond SES, other environmental and behavioral variables emerge as strong predictors of fatality. Collisions that occur on major arterials or in dark conditions are significantly more likely to result in death across all groups. The presence of an intoxicated driver, for instance, increases the odds of a fatal outcome by roughly 30 to 40 percent, depending on the group. These findings are consistent with existing literature that emphasizes the role of speed, visibility, and impaired driving in traffic fatalities.

Built environment indicators yield more mixed results. While the presence of formal bicycle infrastructure (such as painted bike lanes) does not significantly reduce the likelihood of fatality in most models, higher walkability scores, measured via the EPA's Smart Location Database, are associated with lower fatality risk. This suggests that holistic, pedestrian-oriented urban design may be more impactful than isolated infrastructure interventions in promoting safety.

To better understand how SES shapes risk across groups, we calculated predicted probabilities of fatality across the SES spectrum. For White pedestrians and cyclists, the probability of fatality declines sharply as SES increases. A White cyclist in a low-SES neighborhood has a substantially higher predicted probability of fatality than one in a high-SES neighborhood. For Hispanic individuals, this gradient is present but less steep. For Black cyclists, by contrast, the predicted probability of fatality remains virtually unchanged across SES levels, indicating that the safety dividend of neighborhood affluence is not being realized for this group. In practical terms, a Black cyclist in a high-SES neighborhood faces a fatality risk equal to or greater than that of a White cyclist in a low-SES neighborhood.

Taken together, these findings suggest that while neighborhood SES plays a role in shaping fatality risk, it is not sufficient on its own to address the disparities faced by people of color. The absence of a protective SES effect for Black and Asian individuals points to underlying structural and behavioral inequities, such as differential driver behavior, enforcement patterns, or access to infrastructure, that may persist even in affluent neighborhoods. The results also indicate that traffic safety interventions that focus solely on physical improvements or area-level upgrades may fall short of achieving equity unless they are explicitly designed to address these racialized dynamics. In sum, the analysis demonstrates that race and SES are not interchangeable proxies for traffic risk. Rather, they interact in complex ways that demand a more targeted and nuanced policy response. The next section elaborates on these implications and explores strategies for building more equitable and effective approaches to pedestrian and cyclist safety.

Discussion

This study set out to examine whether disparities in fatal pedestrian and bicyclist collisions by race and ethnicity persist even after controlling for neighborhood-level socio-economic status (SES) and built environment characteristics. It responds to the urgent need to understand the growing crisis of non-motorist traffic fatalities in the United States, especially among historically marginalized communities. Drawing on over a decade of statewide collision data in California and combining it with socio-demographic and environmental indicators, the findings provide strong evidence that race and place interact in complex ways to shape fatality risk, and that socio-economic advantage does not provide the same level of protection for all groups.

The results clearly show that higher neighborhood SES is associated with a reduced likelihood of fatality for pedestrians and cyclists. However, this protective effect is not evenly distributed. White and, to a lesser degree, Hispanic individuals benefit from safer outcomes in high-SES neighborhoods. In contrast, Black cyclists see no statistically significant reduction in fatality risk with increasing SES, and Black pedestrians experience only a modest and marginally significant benefit. Asian pedestrians, similarly, do not show a clear SES-related decline in fatality risk. These patterns persist even after accounting for built environment quality, road characteristics, and collision-specific variables such as driver intoxication, time of day, and weather conditions.

These findings reinforce the central thesis of the study: that structural disparities in traffic safety outcomes are not fully explained by socio-economic conditions. Even in affluent neighborhoods, where infrastructure is likely better and resources more abundant, people of color, particularly Black cyclists, remain disproportionately vulnerable. This suggests that additional, less visible forces are at play. Racialized driver behavior, differential law enforcement practices, and unequal access to or utilization of safety infrastructure may all contribute to a system in which neighborhood affluence alone is insufficient to guarantee safety for non-White pedestrians and cyclists.

These results expand upon prior research that documents elevated collision risks in low-income and majority-minority neighborhoods by showing that the benefits of affluence are conditional. Whereas previous studies have focused on the absence of infrastructure in disinvested communities, this analysis suggests that even where resources are present, their effectiveness may be muted by broader social and institutional dynamics. For example, studies have shown that drivers are less likely to yield to Black pedestrians, especially in affluent areas, and that cycling infrastructure in gentrifying neighborhoods can carry cultural and political meanings that limit its adoption by long-standing residents. These contextual factors likely contribute to the observed disparities in safety outcomes, even within high-SES areas.

By integrating neighborhood typologies, walkability metrics, and multi-level modeling strategies, this research builds on existing literature in a meaningful way. It confirms that environmental conditions matter greatly for pedestrian and cyclist safety, but it also shows that their effects are mediated by race and place. These results point toward the limits of universal safety interventions and highlight the need for strategies that explicitly address equity and structural inequality.

In the context of a national rise in pedestrian and cyclist fatalities, these findings carry important implications. Simply improving infrastructure or raising neighborhood SES is not enough. Public safety campaigns, enforcement efforts, and planning initiatives must be tailored to confront the systemic forces that make roadways more dangerous for people of color. This includes challenging racialized assumptions in traffic enforcement, rethinking the spatial targeting of safety improvements, and amplifying the voices of communities who have historically been excluded from planning processes.

Ultimately, this research underscores that transportation safety is inseparable from broader patterns of racial and spatial inequality. If the goal is to reduce fatalities and promote safe mobility for all, policy must move beyond general solutions and confront the ways in which race and privilege structure the lived experience of the street. Only through this equity-oriented approach can we begin to reverse the troubling trends in pedestrian and cyclist deaths and ensure that public investments in safety truly benefit all communities.

Conclusions and Recommendations

The most important conclusion drawn from this study is that neighborhood socio-economic status (SES) does not uniformly protect pedestrians and bicyclists from fatal traffic collisions. While higher-SES environments are generally associated with lower fatality risk, this benefit is not equitably distributed across racial and ethnic groups. White and, to a lesser extent, Hispanic pedestrians and cyclists experience clear reductions in fatality risk as SES increases. In contrast, Black cyclists receive no measurable safety benefit from living in higher-SES neighborhoods, and both Black and Asian pedestrians experience only marginal improvements, if any. This disparity suggests that socio-economic uplift alone is insufficient to eliminate racial inequities in traffic safety outcomes.

Second, the study finds that standard environmental and behavioral risk factors, such as lighting, roadway classification, driver intoxication, and walkability, remain important predictors of fatality risk. However, these factors alone cannot fully explain the observed disparities across racial lines. The persistent vulnerability of people of color, even in ostensibly “safe” neighborhoods, points to deeper structural forces at work, including racialized driver behavior, inequities in infrastructure deployment and enforcement, and differences in how communities interact with and navigate their built environments.

Although this study relies on comprehensive statewide collision data and robust neighborhood-level indicators, it is constrained by the availability of individual-level exposure data (e.g., pedestrian or cyclist volumes disaggregated by race) and by the limitations of racial and ethnic categorization in administrative records. For example, Hispanic ethnicity is recorded independently of race, and multiracial individuals are aggregated into an “Other” category, potentially masking important within-group differences. These limitations mean that while the models provide strong evidence of disparity, the magnitude of those disparities may be under- or overestimated in certain contexts.

Based on these conclusions, several recommendations emerge. First, transportation safety initiatives must be restructured to explicitly address racial disparities, rather than assuming that universal improvements will yield equal outcomes. Agencies should prioritize equity-focused investments in pedestrian and bicycle infrastructure, particularly in areas with persistent risk that serve large populations of color. These improvements must go beyond the installation of infrastructure alone to include community-informed design, culturally competent safety campaigns, and enforcement strategies that do not exacerbate existing inequities. Second, future efforts should incorporate more granular and disaggregated data collection, especially around cyclist and pedestrian behavior, travel patterns, and enforcement encounters. Integrating these datasets into planning and safety evaluations will help transportation agencies better understand the root causes of persistent racial disparities and enable more effective interventions. Third, spatial risk assessments should be institutionalized as part of routine transportation planning. By identifying and continuously monitoring high-risk areas through spatiotemporal analysis, agencies can direct resources where they are needed most and evaluate the impact of interventions over time. These techniques can and should be incorporated into standard risk-assessment tools, safety audits, and performance-based funding formulas. Finally, federal and state transportation departments should consider incorporating these findings into design standards, prioritization frameworks, and equity assessment tools. Just as cost-benefit analyses now guide project selection, equity-based safety assessments should become a formal requirement for evaluating the distributional impacts of infrastructure investments.

In conclusion, addressing rising pedestrian and cyclist fatalities demands more than better infrastructure; it requires a fundamental rethinking of how race, space, and safety intersect. Equity must become a foundational principle, not an afterthought, in traffic safety policy. Only then can the transportation system serve all users with the same promise of safety, regardless of race, class, or neighborhood.

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